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Ammonium Nitrate Manufacturing Industry Technical Document

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16. ABSTRACT

This report presents information on the emission levels, control techniques, and costs associated with the control of particulate emission sources and facilities in the ammonium nitrate solids producing industry. Sources of emissions include prill towers, granulators, predryers, dryers, and coolers. Alternative control techniques and supporting data are described and discussed, and an analysis of environmental and economic impacts of control techniques are presented.

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1.0 INTRODUCTION AND SUMMARY

1.1 PURPOSE

The purpose of this document is to present information on the emission levels, control techniques and costs associated with the control of particulate emission sources and facilities in the ammonium nitrate (AN) solids producing industry. The industry, emission sources and existing control techniques are described and discussed. Control of solution formation processes and emissions are not discussed, although uncontrolled emissions data are presented.

1.2 SUMMARY

1.2.1 Industry Structure

The ammonium nitrate industry produces AN in both solid and solution form. Solids are primarily manufactured in three sizes: high density prills, low density prills and granules. High density prills and granules are used as fertilizer, while low density prills are used as fertilizer or in explosives. Ammonium nitrate solutions are used as fertilizer or are concentrated for use in solids formation processes. There are 66 plants in the United States producing either AN solution alone or both solution and solids. In 1980, ammonium nitrate production is expected to be 10.08 Tg (11.10 million tons).

1.2.2 Processes and Emissions

The production of AN can be divided into several steps or unit processes. Unit processes in the ammonium nitrate industry include AN solution synthesis, solution concentration, solids formation (prilling and granulation), solids finishing, solids screening, solids coating, and bagging and/or bulk shipping. Uncontrolled AN particulate emission rates from these unit processes range from 0.03 g/kg (0.06 lb/ton) of AN produced for the concentration process to 147.2 g/kg (294.6 lb/ton) of AN produced for a solids producing process (granulation). The most effective control device used to control AN particulate emissions is a wet scrubber.

1.2.3 Model Plants and Control Alternatives

Model plants represent ammonium nitrate plants currently operating and those expected to be constructed, modified or expanded in the near future. The model plants defined in this study have production capacities that range from 181 Mg/day (200 tons/day) to 1089 Mg/day (1200 tons/day). Control devices that exhibit various levels of removal efficiency were identified for each source within the model plants. Several control alternatives were selected for each model plant. The control alternatives are based upon combinations of control devices applied to the emission sources within the plant.

1.2.4 Economic and Environmental Impacts

Table 1-1 presents a summary of the control alternatives applied to the model plants. The impact of these control alternatives on the product price and the amount of particulate emissions is presented in Table 1-2. Based on a product price of $100/Mg ($91/ton), the control alternatives increase product price from 2 to 11 percent. Environmental impacts which could result from applying emission control devices include water quality, solid waste, and primary and secondary air quality impacts. There are no water quality or solid waste impacts attributable to the use of wet scrubbers for AN emissions control.

The primary air quality impact is the reduction in particulate emissions from sources in the ammonium nitrate industry. Reductions over existing levels of control range from 46 to 93 percent for prilling plants and 68 percent for granulation plants. Small secondary air impacts exist due to increased power plant particulate emissions resulting from the energy requirements of the control devices. A negative secondary air impact occurs because the energy requirements for the control alternatives are less than the energy requirements for the existing levels of control. The percent secondary impact relative to plant-wide emission reductions ranges from -0.7 percent for a high density prill plant to 1.4 percent for a low density prill plant.

TABLE 1-1. SUMMARY OF CONTROL ALTERNATIVES*

Model Plant Number		Control Alternative	Prill Tower	Cooler
H 1-3	High Density Prilling	1 (ELOC)	0	0
		2	0	X
		3	X (Option 1)	X
		4	X (Option 2)	X
		4a	X (Option 3)	X
			Prill Tower	Predryer, dryer and cooler
L 1-3	Low Density Prilling	1 (ELOC)	0	0
		2	0	X
		3	X (Option 1)	X
		4	X (Option 2)	X
			Granulator	Cooler
G 1-3	Granulation	1 (ELOC)	0	0
		2	X	X

*Options 1, 2, and 3 correspond to different control devices and different levels of control for the prill towers as explained in Chapter 5.

0 - Existing Level of Control (ELOC)
X - Optional Control

TABLE 1-2. IMPACT OF THE CONTROL ALTERNATIVES ON PARTICULATE EMISSIONS AND PRODUCT PRICE

	Production Capacity Mg/Day (Tons/Day)	Ammonium Nitrate Particulate Emissions g/kg AN produced (lb/ton AN produced)					Effect of Control Alternative on Product Price $/Mg AN produced ($/ton AN produced)				
		Control Alternatives					Control Alternatives				
		1	2	3	4	4a	1	2	3	4	4a
High Density Prill Plants											
H-1	363 (400)	1.40 (2.80)	0.75 (1.50)	0.30 (0.60)	0.10 (0.20)	0.10 (0.20)	3.77 (3.42)	3.84 (3.58)	3.31 (3.00)	8.36 (7.58)	2.61 (2.37)
H-2	726 (800)	1.40 (2.80)	0.75 (1.50)	0.30 (0.60)	0.10 (0.20)	0.10 (0.20)	3.12 (2.83)	3.25 (2.95)	2.73 (2.48)	7.44 (6.75)	2.25 (2.04)
H-3	1089 (1200)	1.40 (2.80)	0.75 (1.50)	0.30 (0.60)	0.10 (0.20)	0.10 (0.20)	2.87 (2.60)	2.97 (2.69)	2.58 (2.34)	7.22 (6.55)	2.03 (1.84)
Low Density Prill Plants											
L-1	181 (200)	2.80 (5.60)	0.85 (1.70)	0.40 (0.80)	0.20 (0.40)	a	2.88 (2.61)	3.65 (3.31)	6.14 (5.57)	11.29 (10.24)	a
L-2	363 (400)	2.80 (5.60)	0.85 (1.70)	0.40 (0.80)	0.20 (0.40)	a	2.08 (1.89)	2.60 (2.36)	4.35 (3.95)	9.47 (8.59)	a
L-3	816 (900)	2.80 (5.60)	0.85 (1.70)	0.40 (0.80)	0.20 (0.40)	a	1.64 (1.49)	2.05 (1.86)	3.46 (3.14)	7.97 (7.23)	a
Granulation Plants											
G-1	363 (400)	0.95 (1.90)	0.30 (0.60)	a	a	a	-6.25[b] (-5.67)	-6.10[b] (-5.53)	a	a	a
G-2	726 (800)	0.95 (1.90)	0.30 (0.60)	a	a	a	-6.25[b] (-5.67)	-6.10[b] (-5.53)	a	a	a
G-3	1089 (1200)	0.95 (1.90)	0.30 (0.60)	a	a	a	-6.25[b] (-5.67)	-6.10[b] (-5.53)	a	a	a

[a] This alternative does not apply to this model plant.

[b] For granulation plants, the impact on product price would be negative since the value of the recovered product exceeds the control equipment costs.

2.0 THE AMMONIUM NITRATE INDUSTRY

The purpose of this chapter is to describe the ammonium nitrate (AN) industry. Section 2.1 presents the industry structure, history, and growth, while Section 2.2 discusses the types of products and their uses.

2.1 INDUSTRY STRUCTURE

Ammonium nitrate, or Norway saltpeter (NH_4 NO_3), is a hygroscopic colorless solid which is produced from ammonia and nitric acid. Ammonium nitrate is an oxidant containing a high proportion of nitrogen (33.5 percent by weight), which makes it desirable for manufacture of explosives and for use as a nitrogen fertilizer.

During World War II, the ammonium nitrate industry (SIC 28731) was greatly expanded by the U.S. Government in order to manufacture munitions. Following the war, the federal government sold the ammonium nitrate plants to private industries who began marketing ammonium nitrate as a fertilizer. Early product drawbacks and consumer reluctance were soon overcome and ammonium nitrate developed into a major fertilizer compound.

Presently in the United States, 41 companies are operating 66 ammonium nitrate plants. Total 1980 production capacity for the industry is estimated to be 10.08 Tg (11,101,000 tons) of ammonium nitrate. Table 2-1 contains a listing of ammonium nitrate plants, their location, the type of product they manufacture, their production capacity, and the year they began production.

Historically, the Southeast has shown the greatest growth in production capacity, while the Northeast has shown the greatest decline. At present the largest ammonium nitrate producing area lies in the central and southeastern part of the country. The top six AN producing states, Kansas, Missouri, Oklahoma, Louisiana, Mississippi and Georgia, account for 47 percent of total U. S. ammonium nitrate production capacity.[1]

TABLE 2-1. AMMONIUM NITRATE PRODUCERS -- PLANTS, LOCATIONS, AND CAPACITIES[2]

Company Name	Plant Location	Annual Capacity (10^3 Mg)	Form of AN[a]	Date on Stream
Air Products and Chem. Inc.	Pensacola, FL	181	Solutions, HD prills	1956
Allied Chemical Corp.	Helena, AR	91	Solutions	1967
	Geismar, LA	365	Solutions	1967
	Omaha, NB	102	Solutions	1956
American Cyanamid Co.	Hannibal, MO	150	HD & LD prills	1966
Apache Powder Co.	Benson, AZ	112	LD prills	1945
Bison Nitrogen Products	Woodward, OK	105	Solutions	1978
Calumet Nitrogen	Hammond, IN	50		N/A
Center Plains Industries	Odessa, TX	75	Solutions, (captive for nitrogen solutions)	N/A
CF Industries, Inc.	Donaldsonville, LA	203	Solutions	1978
	Fremont, NB	30	Solutions	1966
	Orlean, NY	64	Solutions	1967
	Terre Haute, IN	145	Solutions, LD prills	1964
	Tunis, NC[b]	363	Solutions, HD prills	1969
	Tyner, TN	213	Solutions, HD prills	1962
The Coastal Corp. Wycon Chem. Co.	Cheyenne, WY	66	Solutions, HD prills	1965
Columbia Nitrogen Corp.	Augusta, Ga	539	Solutions, LD & HD prills	1963
Cominco American, Inc.	Beatrice, NB	157	Granular	1966
E.I. Dupont de Nemours & Co.	Seneca, IL	179	HD & LD prills	1967
Escambia Chemicals	Pace, FL	90	HD prills	1980
Esmark, Inc. Estech Gen. Chems. Corp.	Beaumont, TX	181	Solutions, HD prills	1967
Farmland Industries, Inc.	Dodge City, KS	73	Solutions	1975
	Lawrence, KS	417	Solutions, HD prills	1954
Getty Oil Co. Hawkeye Chem. Co., subs.	Clinton, IA	132	Solutions, HD & LD prills	1963
Goodpasture, Inc.	Dimitt, TX	28	Solutions	1971
W. R. Grace and Co.	Wilmington, NC	197	Solutions, LD prills	1963
Gulf Oil Co.	Pittsburg, KS	387	LD prills	1940
Hercules, Inc.	Bessemer, AL	23	Grains	1955
	Carthage, MO	14	Grains	1966
	Donora, PA	136	LD prills	1969
	Hercules, CA	126	Solutions, LD prills	N/A
	Louisiana, MO	454	Solutions, LD prills	1961
Illinois Nitrogen Corp.	Marseilles, IL	126	Solutions, HD prills	1964
Kaiser Aluminum & Chem. Co.	Bainbridge, GA	54	Solutions	1965
	North Bend, OH	95	Solutions	1965
	Savannah, GA	229	Solutions, LD prills	1957
	Tampa, FL	47	Solutions	1960
Mississippi Chem. Co.	Yazoo City, MS	562	Solutions, HD prills	1951

TABLE 2-1. (continued)

Company Name	Plant Location	Annual Capacity (10^3 Mg)	Form of AN[a]	Date on Stream
Monsanto Co.	El Dorado, AR	227	HD prills	1949
	Luling, LA	181	HD & LD prills	1954
Nitram, Inc.	Tampa, FL	272	Solutions, LD prills	1963
N-Ren Corporation	Carlsbad, NM	87	LD prills	1976
	E. Dubuque, IL	83	Solutions	N/A
	Pine Bend, MN	209	Solutions, HD & LD prills	1962
	Pryor, OK	139	Solutions, granular	1967
Occidental Chemical Co.	Hanford, CA	20	Solutions	1965
Phillips Pacific Chem. Co.	Finley, WA	40	Solutions	1963
Phillips Petroleum Co.	Beatrice, NB	68	Solutions,	1965
	Etter, TX	163	LD prills	1950
Reichhold Chemicals	St. Helens, OR	22	Solutions	1968
J. R. Simplot Co.	Pocatello, ID	18	Solutions	1974
Standard Oil of CA Chevron Chem. Co.	Fort Madison, IA	172	Solutions, granular	1961
	Kennewick, WA	214	Solutions, granular	1960
	Richmond, CA	68	Solutions	N/A
Standard Oil of Ohio Vistron Corp., subs.	Lima, OH	58	Solutions	1956
Tennessee Valley Authority	Muscle Shoals, AL	39	Solutions	1972
Terra Chems. International	Port Neal, IA	130	Solutions, HD prills	1967
Tyler Corp. Atlas Powder Corp., subs.	Joplin, MO	146	HD & LD prills	1958
	Tamaqua, PA	14	Crystal	1956
Union Oil of California	Brea, CA	113	Solutions, HD prills	1955
U. S. Army	Kingsport, TN	N/A	N/A	1967
U. S. Steel Corp.	Cherokee, AL	136	Solutions, HD prills	1962
	Crystal City, MO	223	Solutions, LD prills	1954
	Geneva, UT	91	LD prills	1957
Valley Nitrogen Producers	EL Centro, CA	40	Solutions	1968
	Helm, CA	40	Solutions	1976
Williams Co. Agrico Chem. Co.	Verdigris, OK	478	Solutions	1975
Total U. S. domestic capacity		10,081		

[a] LD = Low density prills; HD = High density prills.

[b] Temporarily closed.

Table 2-2 presents the historical production capacity and utilization of the ammonium nitrate industry. Ammonium nitrate production capacity has more than doubled since 1960, with major expansion occurring between 1961 and 1969. Due to fluctuations in the market, ammonium nitrate plants have historically operated at between 63 and 87 percent of capacity. The average utilization has been 70.5 percent. The largest utilization occurred in the years 1974-1975, when an increase in energy and feedstock prices, along with a high world demand for fertilizer caused a significant increase in ammonium nitrate demand.

2.2 AMMONIUM NITRATE PRODUCTS AND USES

Ammonium nitrate (AN) is formed by reacting ammonia and nitric acid to produce an 83 percent aqueous ammonium nitrate solution. This solution may be sold for use as a fertilizer, or may be further concentrated to form a 95-99.5 percent ammonium nitrate melt for use in solids formation processes. Solid ammonium nitrate may be produced by prilling, graining, granulation or crystallization. In addition, prills can be produced in either high or low density form, depending on the concentration of the melt. High density prills, granules and crystals are used as fertilizer. Ammonium nitrate grains are used solely in explosives. Low density prills can be used as fertilizer or in explosives.

In 1979, 77 percent of all ammonium nitrate produced (both solution and solid) was used as fertilizer.[3] In 1980, it is estimated that the ammonium nitrate industry will have a final product yield of 5.31 Tg (5,840,000 tons) of solids and 4.77 Tg (5,250,000 tons) of AN solution.[2] Table 2-3 presents the number of plants and their total production capacity by the type of solid ammonium nitrate they produce. As can be seen from Table 2-3, prilling plants now represent the bulk of the solid producing capacity.

Prior to World War II, graining was the primary method of solids production. Then low density prills replaced grains in the explosives market and high density prills were used in the fertilizer market. So after the war, most new installations were designed to produce prills. Since 1960 another trend has developed; granules have started making

TABLE 2-2. AMMONIUM NITRATE PRODUCTION, CAPACITY, AND CAPACITY UTILIZATION RATES[2]

Year	Production (10^3 Mg)	Capacity (10^3 Mg)	Capacity utilization (percent)
1961	2,883	4,017	71.7700
1962	2,981	4,239	70.3232
1963	3,336	4,720	70.6780
1964	3,867	5,377	71.9174
1965	4,203	6,013	69.8986
1966	4,467	7,071	63.1735
1967	5,137	7,617	67.4412
1968	5,448	7,804	69.8104
1969	5,089	8,157	62.3881
1970	5,641	8,025	70.2928
1971	6,025	8,124	74.1630
1972	6,164	7,888	78.1440
1973	6,251	7,843	79.7016
1974	6,649	7,637	87.0630
1975	6,771	7,995	84.6904
1976	6,353	8,250	77.0061
1977	6,771	8,317	81.4116
1978	6,645	8,478	78.3793
1979	7,074	9,315	75.9420

TABLE 2-3. NUMBER OF PLANTS BY TYPE OF SOLID PRODUCED AND CAPACITY, 1980[2]

Product	Number of plants	Estimated production capacity (10^3 Mg)
Prills		
Low density	10	1,276
High density	12	1,396
Low and high density	7	1,880
Total prilling	29	4,552
Granules	6	611
Grains	2	37
Crystals	1	14
Total Solid	38	5,314

inroads into the high density prill market. This is partly due to the fact that granules have more abrasion resistance and a higher crushing strength than prills.

Within the United States, ammonium nitrate competes with a number of other nitrogenous fertilizers. The major competitors are anhydrous ammonia, aqueous ammonia, nitrogen solutions, urea and ammonium sulfate. Since 1974, the demand for ammonium nitrate fertilizers has been decreasing, particularly for solid ammonium nitrate fertilizers. In 1979, ammonium nitrate accounted for 11 percent of all nitrogen consumed in the United States as fertilizer.[4] The increasing use of urea fertilizer is one reason for the decline. However, in contrast to the decreasing demand for solid ammonium nitrate fertilizers, ammonium nitrate explosives demand has risen steadily.[3] Currently there are no economically viable alternatives to ammonium nitrate for use in explosives.

2.3 REFERENCES

1. Bridges, J.D. Fertilizer Trends 1979. Bulletin No. Y-150. Muscle Shoals, Alabama, TVA National Fertilizer Development Center. January 1980. pp. 41-42.

2. Memo from Ramachandran, V., Research Triangle Institute, to Rader, R., Radian Corporation. January 6, 1981. 6 p. Information about data stored in Triangle University Computing Center.

3. Reference 1, p. 14.

4. Reference 1, p. 12.

3.0 PROCESSES AND THEIR EMISSIONS

3.1 INTRODUCTION

This chapter describes uncontrolled emissions from the ammonium nitrate (AN) processing industry. Section 3.1 presents the basic AN process chemistry, a manufacturing overview and an emissions overview. Section 3.2 describes each process and presents its emissions.

3.1.1 Process Chemistry

Ammonium nitrate is produced as an aqueous solution by the neutralization of nitric acid with ammonia. The reaction is represented by the equation:

$$HNO_3(aq) + NH_3(g) \longrightarrow NH_4NO_3(aq) + \text{heat}$$

Typically, a 56 to 60 weight percent nitric acid solution is mixed with gaseous ammonia in a ratio ranging from 3.55-3.71 to 1 by weight. This feed ratio produces an 83 weight percent ammonium nitrate product. The reaction is an acid-base neutralization which liberates 46.5 to 52.4 MJ (44 to 50 thousand Btu's) of heat per mole of ammonium nitrate formed, depending on the concentration of the nitric acid feed. This reaction is typically carried out at atmospheric pressure, with the temperature between 405 and 422 K (270-300°F).

Rosser et al. reports that ammonium nitrate can decompose or dissociate as described by the following reactions:[1]

$$\text{decomposition} \quad NH_4NO_3\ (l) \longrightarrow N_2O(g) + 2H_2O(g) + \text{heat}$$

$$\text{dissociation} \quad NH_4NO_3\ (l) \longleftrightarrow NH_3(g) + HNO_3(g) - \text{heat}$$

Decomposition, an irreversible reaction, is small at temperatures below 505 K (450°F). Dissociation of ammonium nitrate, which is reversible, is favored by increasing temperatures because it is an endothermic reaction. The dissociation reaction is responsible for ammonium nitrate fume, a significant contributor to emissions during solids formation, as discussed in Section 3.2.

Ammonium nitrate also alters its crystalline state at various temperatures. Table 3-1 shows that ammonium nitrate typically passes through four crystalline states after becoming solid at 443.6 K (339°F). Rapid transitions between the various crystalline states can result in fracturing of the AN particles, which leads to AN dust emissions.

TABLE 3-1. PROPERTIES OF SOLID AMMONIUM NITRATE[2]

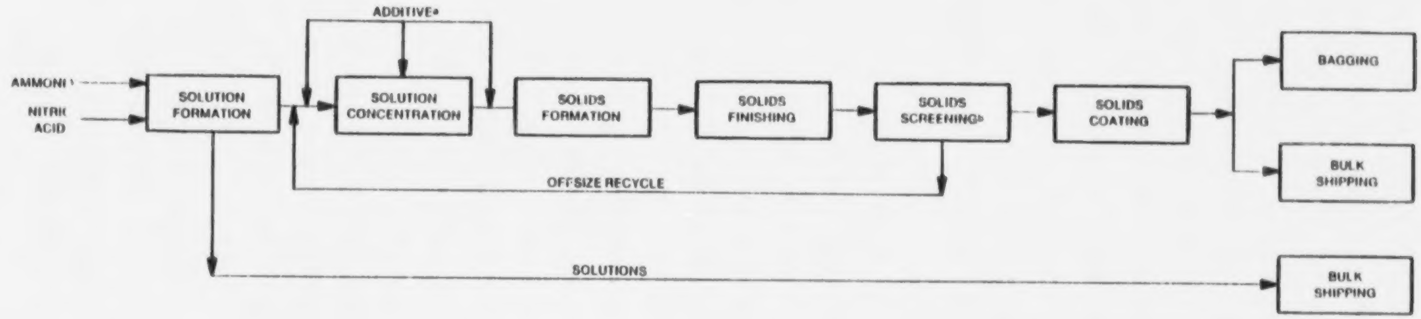
Melting Point -- 443.6 K (339°F)
Solubility,
@ 273 K (32°F) -- 118 g/100 g water
@ 373 K (212°F) -- 843 g/100 g water

Crystal States	Temperature, K (°F)	Morphology
I	443 to 398 (338 to 257)	ϵ cubic
II	398 to 357 (257 to 183.2)	δ tetragonal
III	357 to 305 (183 to 89.6)	γ rhombic
IV	305 to 255 (89.6 to -0.4)	β rhombic
V	below 255 (below -0.4)	α tetragonal

3.1.2 Process Overview

The process for manufacturing ammonium nitrate (AN) contains up to seven major unit operations. The basic arrangement of these operations is shown in Figure 3-1. These major operating steps are:

(1) Solution formation or synthesis
(2) Solution concentration
(3) Solids formation
(4) Solids finishing
(5) Solids screening
(6) Solids coating
(7) Bagging and/or bulk shipping


ADDITIVE^a
AMMONI
NITRIC ACID
SOLUTION FORMATION
SOLUTION CONCENTRATION
SOLIDS FORMATION
SOLIDS FINISHING
SOLIDS SCREENING^b
SOLIDS COATING
BAGGING
BULK SHIPPING
OFFSIZE RECYCLE
SOLUTIONS
BULK SHIPPING

[a] ADDITIVE MAY BE ADDED BEFORE, DURING OR AFTER CONCENTRATION

[b] MAY BE BEFORE OR AFTER SOLIDS FINISHING

Figure 3-1. Ammonium nitrate processing steps.

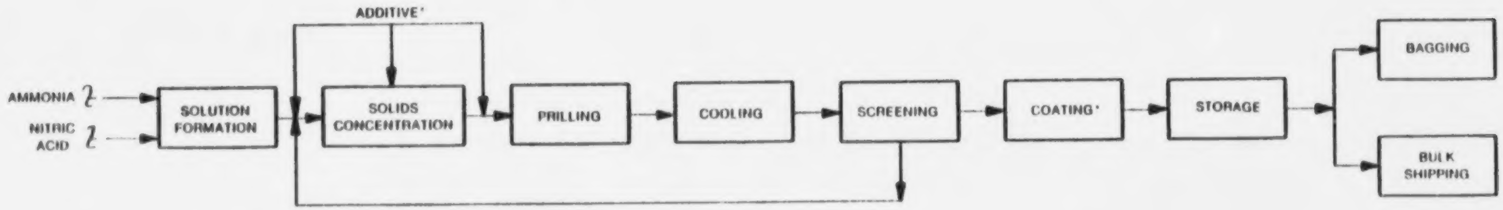
The number of operating steps employed is determined by the desired end product. Plants producing AN solutions alone utilize only the first and seventh unit operations, solution formation and bulk shipping. Facilities producing solid AN can employ all of these operations.

All AN plants produce an aqueous AN solution (Step 1) by reacting ammonia and nitric acid in a neutralizer to yield an 83 percent aqueous AN solution. The solution can be sold as a liquid nitrogen fertilizer or can be further concentrated to make solid AN. The ammonium nitrate solution is concentrated in an evaporator or concentrator using heat to drive off additional water (Step 2). A melt containing from 95 to 99.8 percent AN at approximately 422 K (300 °F) is produced. The melt is then used to make solid AN product.

Of the various processes used to produce solid AN (Step 3), prilling and granulation are the most common. Figures 3-2, 3-3, and 3-4 are flow diagrams of ammonium nitrate high density prilling, low density prilling, and rotary drum and pan granulation plants, respectively.

To produce prills, concentrated AN melt is sprayed into a prill tower. Ammonium nitrate droplets form in the tower and fall countercurrent to a rising air stream that cools and solidifies the falling droplets into spherical "prills". Prill density can be varied by using different concentrations of ammonium nitrate melt. Low density prills are formed from a 95 to 97.5 percent ammonium nitrate melt; high density prills are formed from a 99.5 to 99.8 percent melt. High density prills are less porous than low density prills.

In the prilling process, many manufacturers inject an additive in the melt stream. Magnesium nitrate or magnesium oxide, for example, is added to the melt stream at a rate that results in 1 to 2.5 weight percent of additive in the final product. This additive serves three purposes: it raises the crystalline transition temperature of the solid final product; it acts as a desiccant, drawing water into the final product prills to reduce caking; and it allows prilling to be conducted at a lower temperature by reducing the freezing point of molten AN.[3]


AMMONIA
NITRIC ACID
SOLUTION FORMATION
ADDITIVE*
SOLIDS CONCENTRATION
PRILLING
COOLING
SCREENING
COATING*
STORAGE
BAGGING
BULK SHIPPING

*OPTIONAL

Figure 3-2. High density ammonium nitrate prilling process flow diagram.

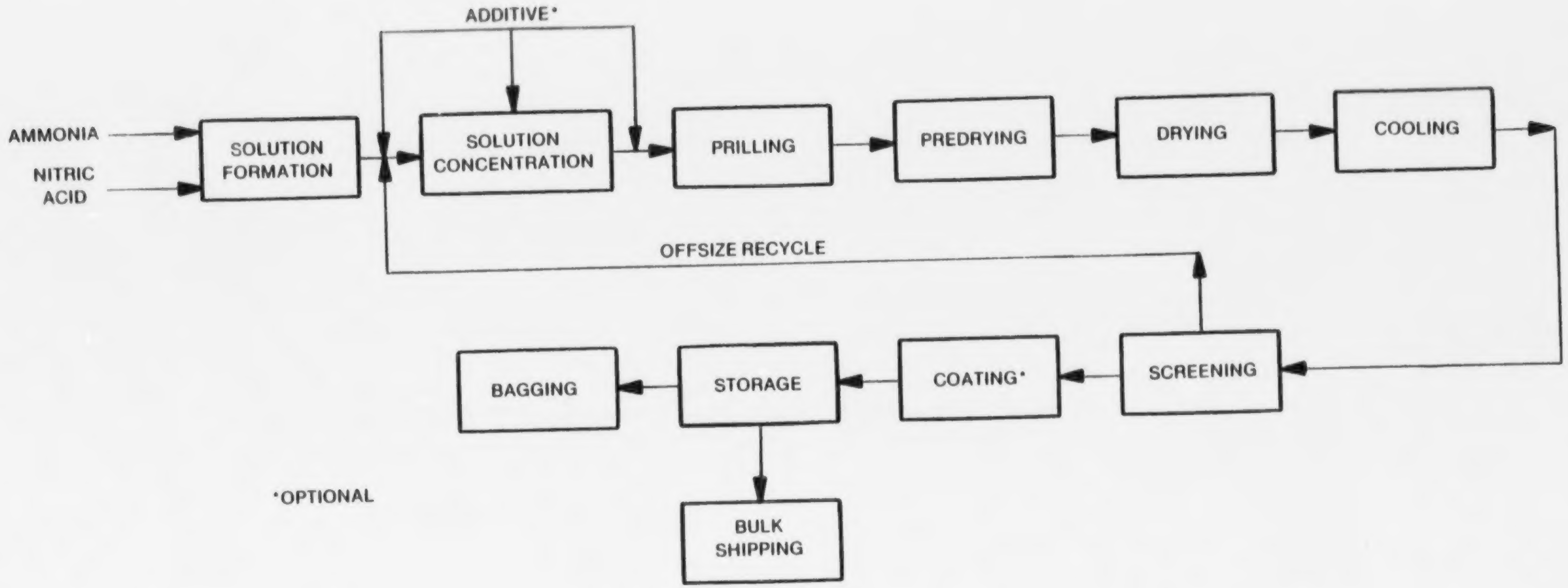

ADDITIVE*
AMMONIA
NITRIC ACID
SOLUTION FORMATION
SOLUTION CONCENTRATION
PRILLING
PREDRYING
DRYING
COOLING
OFFSIZE RECYCLE
SCREENING
COATING*
STORAGE
BAGGING
BULK SHIPPING
*OPTIONAL

Figure 3-3. Low density ammonium nitrate prilling process flow diagram.

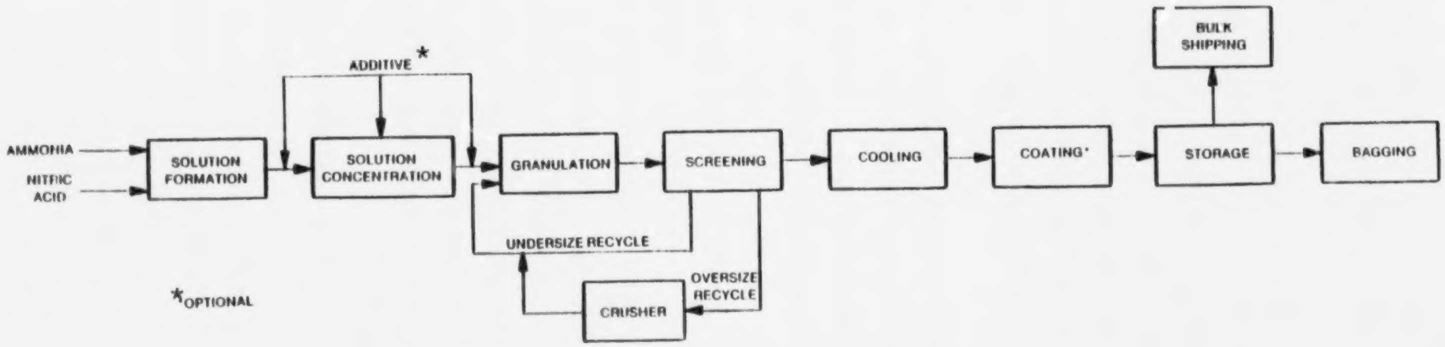

AMMONIA
NITRIC ACID
SOLUTION FORMATION
ADDITIVE *
SOLUTION CONCENTRATION
GRANULATION
SCREENING
UNDERSIZE RECYCLE
OVERSIZE RECYCLE
CRUSHER
COOLING
COATING*
STORAGE
BULK SHIPPING
BAGGING
*OPTIONAL

Figure 3-4. Drum granulation or pan granulation process flow diagram.

Rotary drum granulators produce granules by spraying a concentrated AN melt (99.0 to 99.8 percent AN) onto small seed particles in a long rotating cylindrical drum. As the seed particles rotate in the drum, successive layers of AN are added to the particles, forming granules. Granules are removed from the granulator and screened; offsize granules are crushed and recycled to the granulator to supply additional seed particles or dissolved and returned to the solution process.

Pan granulators operate on the same principle as drum granulators, producing a solid product with similar physical characteristics. However, in the pan granulation process solids are formed in a large, rotating circular pan.

Sandvik belts and graining kettles are less popular solids forming process equipment. The solids they produce are softer and smaller than granules from a rotary drum granulator and are used in the production of packed explosives. Graining kettles are expected to decline in the future because they are costly and generally more hazardous to operate.[4,5]

The temperature of the AN product exiting the solids formation process is approximately 339-397 K (150-255°F). Rotary drum or fluidized bed coolers prevent deterioration and agglomeration by cooling the solids prior to storage and shipping. Low density prills, which have a high moisture content because of a lower melt concentration, require drying before cooling. They are usually dried in two stages, predrying and drying. Rotary drum or fluidized bed predryers and dryers are used for drying. Predryers, dryers and coolers are referred to as finishing equipment in this report (Step 4).

The solids are produced in a wide variety of sizes and must be screened to produce consistently sized prills or granules. Cooled prills are screened and offsize prills are dissolved and recycled to the solution concentration process. Granules are screened prior to cooling. Any undersize particles are returned directly to the granulator; oversize particles may either be crushed and returned to the granulator or sent to the solution concentration process (Step 5).

Following screening, products can be coated in a rotary drum coater (Step 6) to prevent agglomeration during storage and shipment. The most common coating materials are clays and diatomaceous earth. However, the use of additives in the AN melt may preclude the use of coatings.

Solid AN is stored and shipped either in bulk or in bags (Step 7). Approximately 10 percent of solid AN produced in the U. S. is bagged.[6]

3.1.3 Emissions Overview

Ammonium nitrate production processes can emit particulates (NH_4NO_3, and coating materials), ammonia and nitric acid. Table 3-2 summarizes EPA test data on uncontrolled emissions from AN production processes.

Particulate emissions, consisting primarily of AN, are emitted from neutralizers, evaporator/concentrators, prilling towers, granulators and solids finishing and handling operations. EPA tests show that ammonium nitrate emissions from individual sources range from 0.03 to 147.2 g/kg (0.06 to 294.6 lb/ton) of ammonium nitrate produced.

Ammonia can be emitted from neutralizers, evaporators/concentrators, prilling towers and granulators. These ammonia emissions, according to EPA tests, range from 0.03 to 29.7 g/kg (0.05 to 59.5 lb/ton) of ammonium nitrate produced.

When operating under acidic conditions, neutralizers can emit nitric acid. EPA has not tested for nitric acid emissions from AN plants but two plants (Plants M and T) have reported emissions of 0.004 g/kg (0.009 lb/ton) and 0.08 g/kg (0.16 lb/ton) of ammonium nitrate produced, respectively.[7]

3.2 DESCRIPTION OF PROCESSES AND EMISSIONS

This section will give an in-depth description of each process and its emissions. A detailed analysis of the process operating parameters, particulate emissions and factors that affect these emissions are presented for the solids formation and solids finishing operations. Particulate emissions from solution formation, screening, coating, handling and bagging operations are discussed in this chapter but are not discussed

TABLE 3-2. EPA TEST DATA ON UNCONTROLLED EMISSIONS FROM SOURCES IN THE AMMONIUM NITRATE INDUSTRY[8]

Emission Source	Emission Constituents: Ammonium Nitrate[a] Particulate g/kg (lb/ton)	Emission Constituents: Ammonia[b] g/kg (lb/ton)
Solution formation		
neutralizer	2.6 (5.3)	18.0 (36.0)[c]
evaporators/concentrators	0.03-0.07 (0.06-0.14)	0.066-4.2 (0.13-8.3)
Solids formation		
low density prill tower	0.39 (0.78)	0.13 (0.26)
high density prill tower	1.6 (3.2)	28.6 (57.2)
drum granulator	147.2 (294.6)	29.7 (59.5)
pan granulator	1.34 (2.68)	0.07 (0.15)
Solids finishing		
LD predryer	10.1-37.3 (20.2-74.6)	0-0.29 (0-0.58)
LD dryer	11.4-93.7 (22.8-187.4)	0-1.3 (0-2.6)
LD cooler	12.3-37.8 (24.5-75.7)	0-0.29 (0-0.58)
HD cooler	0.83 (1.66)	0-0.03 (0.05)
Rotary drum granulator cooler	7.5-8.6 (15-17.3)	0-1.2 (0-2.3)
Pan granulator precooler	18 (36)	0 0
Pan granulator cooler	0.25 (0.49)	0 0

[a] $\frac{\text{g (lb) Ammonium Nitrate Emitted}}{\text{kg (ton) Ammonium Nitrate Produced}}$

[b] $\frac{\text{g (lb) Excess Ammonia Emitted}}{\text{kg (ton) Ammonium Nitrate Produced}}$

[c] Neutralizer operating with excess NH_3.

afterward. Ammonia and nitric acid emissions are also presented in this chapter; but they also are not discussed further in this document.

3.2.1 Neutralization

The reaction between nitric acid and ammonia, an exothermic acid-base neutralization, is carried out in a reactor or neutralizer. A 55 percent nitric acid stream is used in the reaction to produce a 61 percent ammonium nitrate solution. The heat generated in this reaction is used to drive off a portion of the remaining water, further concentrating the solution to 83 percent ammonium nitrate. The reactor, where neutralization is actually accomplished, can be a one or two-stage unit. In a two-stage operation an excess of nitric acid is fed to the first stage reactor. The reaction products from the first stage flow to a second reactor where additional ammonia is introduced to insure that all of the nitric acid reacts.[9]

A single-stage reactor (Figure 3-5) may operate with excess ammonia (NH_3), excess nitric acid (HNO_3) or under neutral concentrations. Most plants today operate the neutralizer with excess ammonia. Reactors are operated under pressure, at atmospheric pressure or under a vacuum. There are several types of single-stage neutralizers used in the industry; these include thermosyphon, forced circulation, tank type units and a proprietary system developed by Mississippi Chemical Company.

Emissions occur when steam is liberated during the course of the exothermic neutralization reaction. Emissions of ammonium nitrate and ammonia or nitric acid occur as this steam is vented from the neutralizer vessel. Ammonia emissions are a result of excess ammonia in the neutralization and nitric acid emission are a result of excess nitric acid. EPA test results of an atmospheric neutralizer operating under excess ammonia are reported in Table 3-2. The ammonium nitrate emissions were measured to be 2.6 g/kg (5.3 lb/ton) of ammonium nitrate produced. Testing details can be found in Appendix A.

3.2.2 Evaporation/Concentration

The 83 percent AN solution produced in the neutralizer is concentrated further by heating the solution in an evaporator. This step yields a

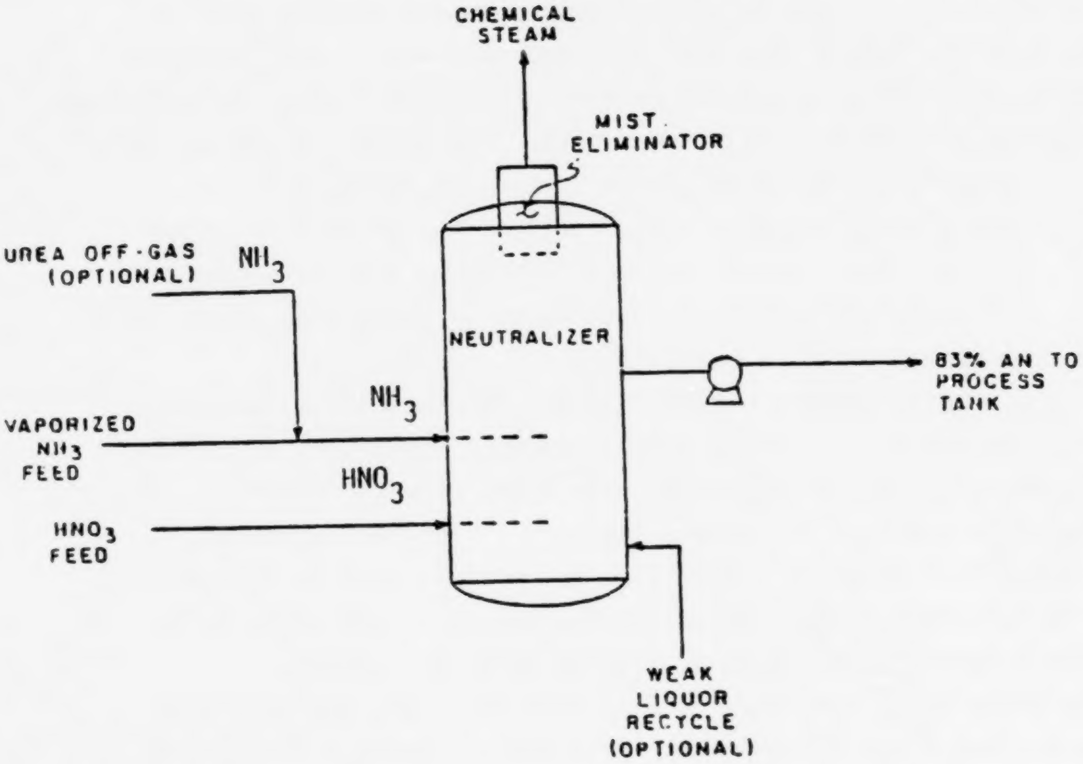

CHEMICAL STEAM
MIST ELIMINATOR
UREA OFF-GAS (OPTIONAL)
NH3
NEUTRALIZER
83% AN TO PROCESS TANK
NH3
VAPORIZED NH3 FEED
HNO3
HNO3 FEED
WEAK LIQUOR RECYCLE (OPTIONAL)

Figure 3-5. Single stage neutralizer.

95 to 97.5 percent melt for low density production or a 99.5+ percent melt for high density prill production and granulation. Concentrators employed in the AN industry usually operate at atmospheric pressure, with a temperature of approximately 423 K (302°F). However, some concentrators operate under vacuum. Plants producing high density prills or granules use either single or double stage evaporation, while plants producing low density prills typically utilize single-stage evaporation.

The air swept falling film evaporator predominates in facilities that employ only single-stage evaporation (Figure 3-6). Plants using double stage evaporation employ many different evaporator types, including forced circulation evaporators, thermosyphon evaporators, calandrias, air swept falling film evaporators and vacuum falling film units. Usually air is used to convey evaporated moisture out of these units.

Emissions of ammonium nitrate, and ammonia or nitric acid occur as the steam and air are vented from the evaporator. Emissions from EPA tested evaporators are reported in Table 3-2. Ammonium nitrate emissions of 0.03 to 0.07 g/kg (0.06 to 0.14 lb/ton) of ammonium nitrate produced were measured. Details of the testing are included in Appendix A.

3.2.3 Prilling

Prilling involves spraying molten ammonium nitrate from the top of a prill tower into a countercurrent stream of air. The spray produces droplets which cool and solidify into prills as they fall. Figure 3-7 is a generalized flow diagram of the prilling operation. Hot ammonium nitrate melt from the concentrators or from storage is delivered to a head tank at the top of the prill tower. The head tank may have a return line to the feed tank to allow liquid level control. The ammonium nitrate melt flows from the head tank to a spray device which forms droplets that fall through the prill tower. As they cool, the droplets form prills.

Two spray devices are employed in the industry, spray plates or heads (Figure 3-8), and spinning buckets (Figure 3-9). Spray plates are the most common. A stream or jet of AN melt is produced as the melt is

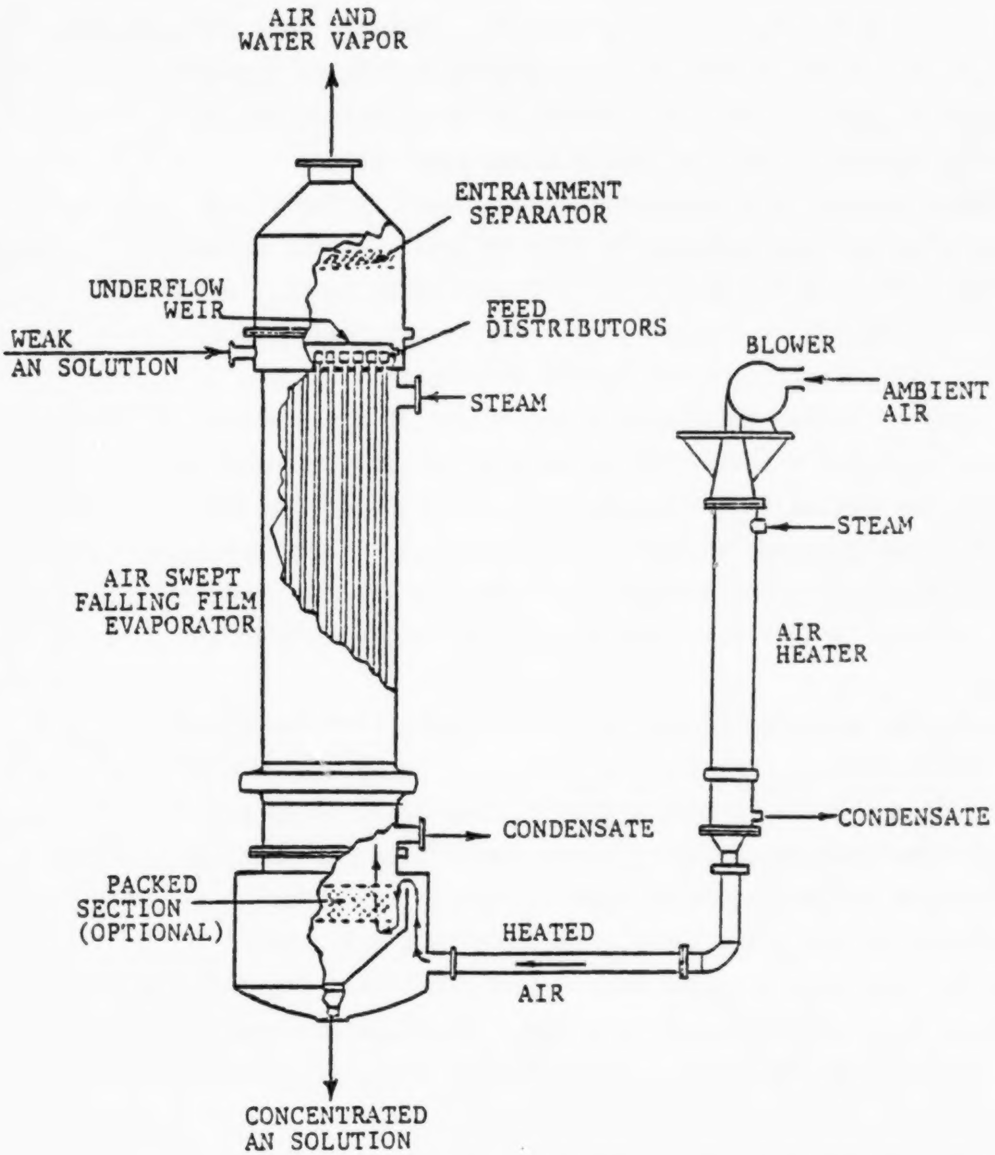

AIR AND
WATER VAPOR
ENTRAINMENT
SEPARATOR
UNDERFLOW
WEIR
FEED
DISTRIBUTORS
WEAK
AN SOLUTION
STEAM
BLOWER
AMBIENT
AIR
STEAM
AIR SWEPT
FALLING FILM
EVAPORATOR
AIR
HEATER
CONDENSATE
CONDENSATE
PACKED
SECTION
(OPTIONAL)
HEATED
AIR
CONCENTRATED
AN SOLUTION

Figure 3-6. Air swept falling film evaporator.

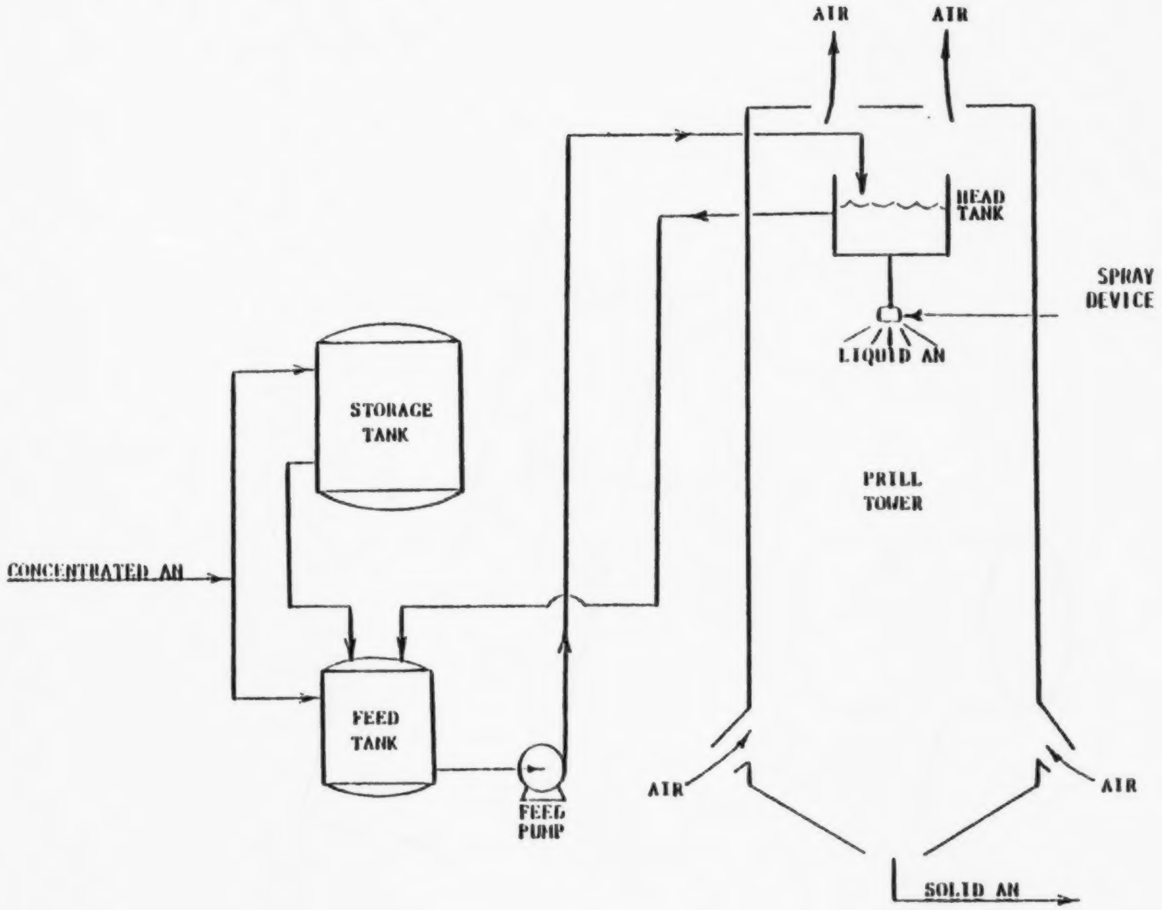

AIR
AIR
HEAD TANK
SPRAY DEVICE
LIQUID AN
STORAGE TANK
PRILL TOWER
CONCENTRATED AN
FEED TANK
FEED PUMP
AIR
AIR
SOLID AN

Figure 3-7. General prill tower flow diagram.

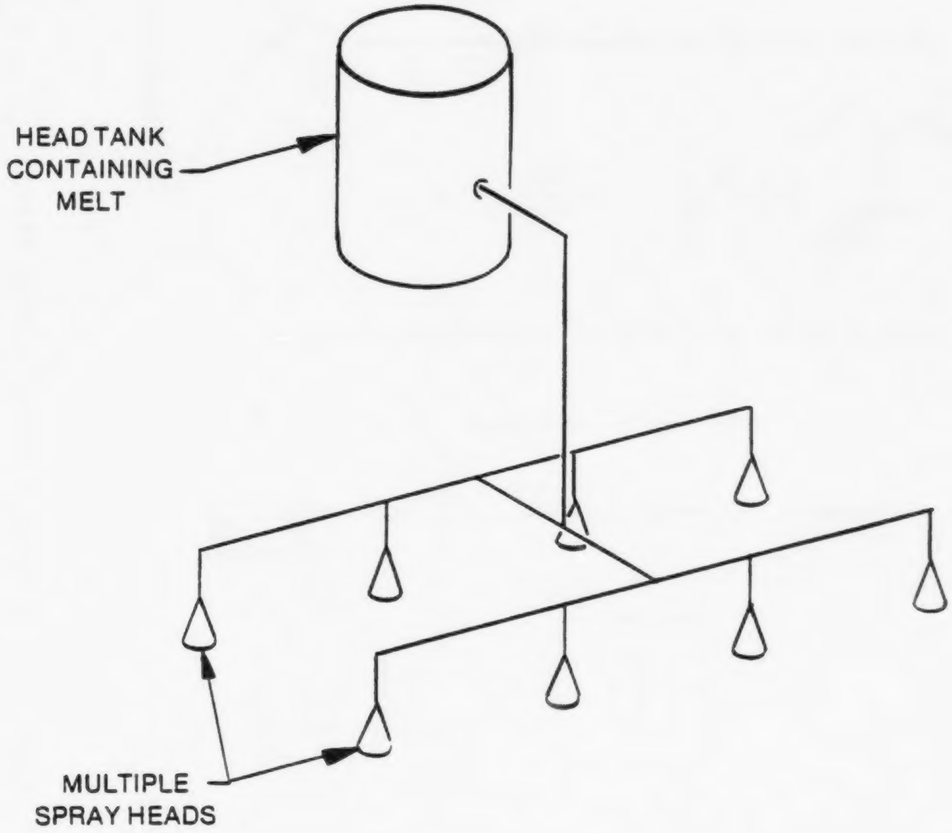

HEAD TANK
CONTAINING
MELT
MULTIPLE
SPRAY HEADS

Figure 3-8. Multiple spray plate or nozzle arrangement.

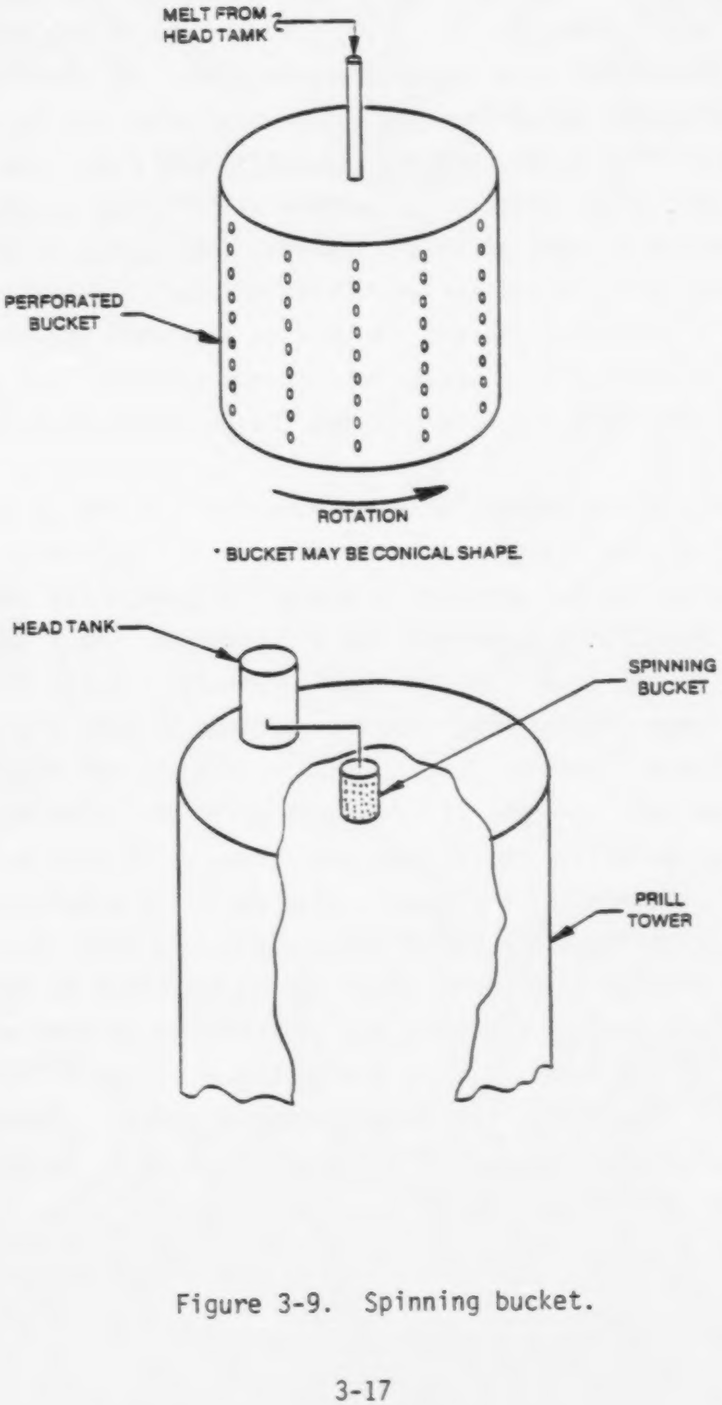

MELT FROM
HEAD TAMK
PERFORATED
BUCKET
ROTATION
* BUCKET MAY BE CONICAL SHAPE.
HEAD TANK
SPINNING
BUCKET
PRILL
TOWER

Figure 3-9. Spinning bucket.

forced through orifices in the spray plate. Spinning buckets produce an AN melt stream by centrifugally forcing the AN melt through orifices. The stream produced by either device breaks up into discrete droplets as it falls through the tower.

Tables 3-3 and 3-4 summarize available information on high and low density prill towers, respectively. Prill towers can have a square, rectangular, multi-sided or circular cross-section. The airflow required for cooling the prills determines the prill tower cross-section. Airflow through the tower must be great enough to sufficiently cool and solidify the droplets, but not so large as to produce an air velocity that would cause excessive entrainment of AN particulate. Historically, prill towers have been designed for air velocities of about 2 meters/sec (6 ft/sec).[10] Prill tower height and the airflow necessary for cooling the prills are interdependent. A taller prill tower requires less airflow because the greater fall distance provides the required air contact for proper cooling.

The actual cooling process involves removing both the latent heat of fusion and the sensible heat of the prills as they solidify. This heat is removed by contact with air in the prill tower. Airflow through the tower can be produced by several fan arrangements: fans exhausting out of the top of the tower (induced flow), fans forcing air into the bottom of the tower (forced flow), or fans located at both the top and bottom of the tower (balanced flow). Solid prills are collected at the tower bottom and belt conveyed to subsequent prill finishing equipment.

Prill tower emissions result from the carryover of fine particles and fume by the air exiting the tower. Fine particles originate from the formation of prills and prill breakup. As prills form they are accompanied by smaller microprills which can be entrained in the exhaust air stream. Prill breakup can occur due to attrition as they collide with the walls of the tower, as they are collected at the bottom of the tower, or from a rapid transition between crystal states. Fuming results from the dissociation of ammonium nitrate and is directly proportional

TABLE 3-3. AMMONIUM NITRATE PRILL TOWER PARAMETERS (HIGH DENSITY PRILL PRODUCTION)[7]

Plant	Prill Tower design capacity		Tower cross-sectional area		Tower height	Tower airflow (actual)		Tower air velocity		Droplet formation technique	Pressure head at droplet device	Temperature AN prills	
	Mg/day	(Tons/day)	$meters^2$	$(feet^2)$	Meters (feet)	m^3/min	(cfm)	Meters/s	(fps)		kPa (psig)	K	(°F)
A	567	(625)	42	(452)	46.9[b] (154)	7,219	(254,930)	2.86	(9.40)	Multiple spray plates	--	372	(210)
G	544	(600)	41	(441)	24.4[b] (80)	--	--	--	--	Single spray plate	5.98-11.96 (1.06-2.12)	397	(255)
H[a]	--	--	83.6	(900)	51.8[b] (170)	10,336	(365,000)	2.06	(6.76)	--	14.94 (2.65)	358	(185)
I	838[c]	(922)[c]	33.4	(360)	67.1 (220)	6,286	(222,000)	3.14	(10.28)	Single spray plate	--	389	(240)
M	363	(400)	31.2	(336)	29.9 (98)	3,766	(133,000)	2.01	(6.60)	Multiple spray plates	12.55 (2.23)	389	(240)
N	998	(1,100)	58.1	(625)	61 (200)	16,254	(574,000)	4.66	(15.31)	--	4.48 (0.795)	372	(210)
N	363	(400)	37.2	(400)	36.6 (120)	6,343	(224,000)	2.84	(9.33)	--	4.48 (.795)	372	(210)
P	680	(750)	45	(484)	42.7[b] (140)	4,663	(200,000)	2.10	(6.89)	Single spray plate	--	383	(230)
T	717	(790)	298.9	(3,217)	44.8 (147)	9,061	(320,000)	0.51	(0.166)	Spinning bucket	--	364	(195)

[a] This tower can produce both HD and LD prills - data shown are for HD prill production.

[b] Reported as "free fall" height.

[c] Reported as production capacity.

TABLE 3-4. AMMONIUM NITRATE PRILL TOWER PARAMETERS (LOW DENSITY PRILL PRODUCTION)[11]

Plant	Prill Tower Design Capacity		Tower Cross-Sectional Area		Tower Height	Tower Airflow (Actual)		Tower Air Velocity		Droplet Formation Technique	Pressure Head at Droplet Device	Temperature AN prills	
	Mg/day	(tons/day)	Meters^2	(feet^2)	Meters (feet)	m^3/min	(cfm)	Meters/s	(fps)		kPa (psig)	K	(°F)
C	181	(200)	--	--	--	--	--	--	--	Multiple spray head	14.94^{c} (2.65)	--	--
F	223	(245)	18.2	(196)	42.7^{d} (140)	1,699	(60,000)	1.56	(5.10)	Single spray head	--	355	(180)
H[b]	525	(576)	83.6	(900)	51.8^{d} (170)	8,673	(305,000)	1.72	(5.65)	--	--	350	(170)
J	410	(450)	18.6	(200)	36.6^{d} (120)	2,832	(100,000)	2.54	(8.33)	Multiple spray head	17.93 (3.18)	366	(200)
O	514	(564)	41	(441)	--	4,248	(150,000)	1.73	(5.67)	Single spray head	--	366	(200)
Q	273	(300)	65.4	(704)	54.9 (180)	5,437	(192,000)	1.39	(4.55)	Multiple spray plates	11.96^{c} (2.12)	350	(170)
Z	726	(800)	182.3	(1962)	67.07 (220)	7,796	(275,320)	0.71	(2.34)	Spinning bucket	--	--	--

[a] Data not available.

[b] This tower can produce both HD and LD prills-data shown are for LD production.

[c] Maximum.

[d] Reported as "free fall" height.

to melt temperature. The fume may recombine upon exiting the tower to form sub-micron AN crystals.[12]

Particulate emission rates from prill towers may be affected by the following parameters:

(1) Tower airflow
(2) Spray melt temperature
(3) Condition of spray device orifices and type of spray device
(4) Ambient air temperature
(5) Crystal state changes of solid prills

The effect of these parameters on emissions are discussed in the following paragraphs.

Tower airflow affects emissions because it determines the air velocity in the tower. Increasing tower airflow increases tower velocity thus increasing entrainment of particles. Prill tower emissions may be very sensitive to tower velocity. For example, one study reports that a change in velocity from 1 m/sec to 3 m/sec increases emissions by a factor of 14.[13]

Melt temperature is another significant factor that affects emissions. As the temperature increases, vapor pressure increases, with a corresponding increase in the amount of fume generated. The spray melt temperature depends on specific plant operating practice and whether the product is low or high density prills. Tables 3-5 and 3-6 summarize melt conditions for low and high density production. On the average, the melt spray in high density towers is 24 K (45°F) hotter than low density spray melt. Therefore, it is expected that fume emissions would be greater in high density towers than low density towers.

The condition of the orifices in the spray device can also affect emissions. Orifices should be round and clean to produce round, correctly sized prills. If a hole is partially plugged it can produce prills that are too small, called micro-prills; but more often it will spray in a manner that produces only fine dust. These fines can be entrained by the tower airstream and increase particulate emissions. Furthermore, if a hole is partially plugged so that it sprays at an angle, the sprays

TABLE 3-5. MELT STREAM CHARACTERISTICS FOR LOW DENSITY PRILL PRODUCTION[14]

Plant	Temperature	Percent by Weight Ammonium Nitrate	% H_2O
C	NA	95.0	5.0
F	422 K (300°F)	96.5	3.5
H	425 K (305°F)	96.5	3.5
J	439 K (330°F)	97.0	3.0
O	430 K (315°F)	96.0	4.0
Q	416 K (290°F)	96.0	4.0
Average	426 K (305°F)	96.2	3.8

NA-Not Available

TABLE 3-6. MELT STREAM CHARACTERISTICS FOR HIGH DENSITY PRILL PRODUCTION[14]

Plant	Temperature	% AN[a]	% H_2O[a]
A	450 K (350°F)	98.4	0.5
G	450 K (350°F)	97.7	0.3
H	453 K (356°F)	97.7	0.2
I	450 K (350°F)	99.0	0.5
M	455 K (360°F)	99.8	0.2
N	455 K (360°F)	99.9	0.1
N	458 K (365°F)	99.9	0.1
T	458 K (365°F)	99.0	0.2
Average	450 K (350°F)	98.9	0.3

[a] Does not sum to 100 percent because of the use of additives.

may impinge on one another, creating fine droplets which form ammonium nitrate dust and increase emissions.[15] Spinning buckets tend to have fewer problems with orifice plugging than spray plates. However, spray plates can be vibrated to aid droplet formation and decrease micro-prill formation.[16]

Ambient air is used to cool prills. Changes in ambient temperature affect operation and production parameters, which may affect prill tower emissions. As the air temperature increases, a greater airflow is required to cool the prills. The required summer airflow rate is approximately 40 percent greater than the airflow used during winter operation. If the airflow rate must be increased because of ambient conditions, emissions will increase due to increased entrainment of microprills. Higher ambient air temperatures also cause AN fuming to increase because cooling is slower at the prill surface.[10]

Emissions are also affected by the transition of the prills between crystal states. A rapid transition in crystal state can cause the prill to disintegrate. The resulting dust can become entrained in the prill tower airflow, thus increasing emissions. Low density prills are more sensitive to crystal changes than high density prills, and have a greater tendency to break up into dust because of their larger void spacing.

Emissions data on high and low density prill towers from EPA and industry tests are reported in Table 3-7. Uncontrolled ammonium nitrate emissions from high density prill towers range from 0.81 to 2.74 g/kg (1.63 to 5.48 lb/ton) of AN produced. Industry and EPA test data on emission quantities indicate that uncontrolled ammonium nitrate emissions from low density prill towers range from 0.21 to 0.69 g/kg (0.42 to 1.38 lb/ton) of AN produced. However, industry and EPA data may not be directly comparable because of differences in sampling and analytical procedures.

3.2.4 Granulation

3.2.4.1 Drum Granulation. The drum granulator consists of a rotating horizontal cylinder, either 3.7 or 4.3 m (12 or 14 ft) in diameter, which is divided by a retaining dam into two sections, the

TABLE 3-7. UNCONTROLLED EMISSIONS FROM PRILL TOWERS[a,17]

Plant	Product	Ammonium Nitrate[c]		Ammonia[d]	
		g/kg	(lb/ton)	g/kg	(lb/ton)
A[b]	High Density Prills	1.60	(3.20)	28.6	(57.2)
G	High Density Prills	2.74	(5.48)	-	-
H	High Density Prills	1.16	(2.33)	-	-
I	High Density Prills	1.28	(2.55)	-	-
O	High Density Prills	0.81	(1.63)	-	-
P	High Density Prills	1.93	(3.86)	-	-
C	Low Density Prills	0.21	(0.42)	-	-
J	Low Density Prills	0.22	(0.45)	-	-
L	Low Density Prills	0.69	(1.38)	-	-
V	Low Density Prills	0.60	(1.20)	-	-
W	Low Density Prills	0.47	(0.93)	-	-
X	Low Density Prills	0.49	(0.98)	-	-
Z[b]	Low Density Prills	0.39	(0.78)	0.13	(0.26)

[a] Results of emissions characterization studies conducted by plant personnel unless otherwise noted (Industry data).

[b] Results of a test conducted by EPA as part of this study.

[c] $\frac{\text{g (lb) Ammonium Nitrate Emitted}}{\text{kg (ton) Ammonium Nitrate Produced}}$

[d] $\frac{\text{g (lb) Ammonia Emitted}}{\text{kg (ton) Ammonium Nitrate Produced}}$

granulating section and the cooling section (Figure 3-10). A pipe running axially near the center of the granulating section emits a fine spray of ammonium nitrate melt, typically at a concentration of 99+ percent by weight and at a temperature of 458 K (365°F).[18] Ammonium nitrate seed particles (from offsize product recycle) enter the drum at the granulation end. As the drum rotates, lifting flights in the granulating section pick up the ammonium nitrate seed particles and shower these particles down through the AN melt spray. As the particles pass through the spray, they are coated with molten AN, which cools and hardens on the particles as the lifting flights carry them away from the spray. The particles are showered back down through the spray again coating them with molten AN. This process is repeated; gradually the particles build up to product size through the addition of successive layers of AN. This method of formation gives the granule an onion-skin-like (concentrically layered) structure.[19]

Granulators require less air for operation than prill towers. The air entering the granulator is generally chilled to about 283 K (50°F) and cools the granules to approximately 308 K (95°F) by the time they leave the cooling section of the drum.[18] The countercurrent airflow removes the heat of crystallization of the ammonium nitrate and entrains 10 to 20 percent by weight of the product.[20] The desired product is achieved by controlling the residence time of the particle in the drum.

Particles in the bed tend to segregate according to size; the smaller granules of ammonium nitrate settle down to the bottom to be picked up by lifting flights. The drum operates at a slight angle, so material migrates by gravity towards the cooling section. The larger particles at the top of the bed pass over the retaining dam into the cooling section. After passing through the cooling section, the granules exit the rotary drum and are screened. Undersized particles are separated and recycled as seed material, while oversize granules are either crushed and recycled as seed, dissolved and added to the solution process, or both. The recycle to product ratio for a drum granulator is typically 2:1.[20]

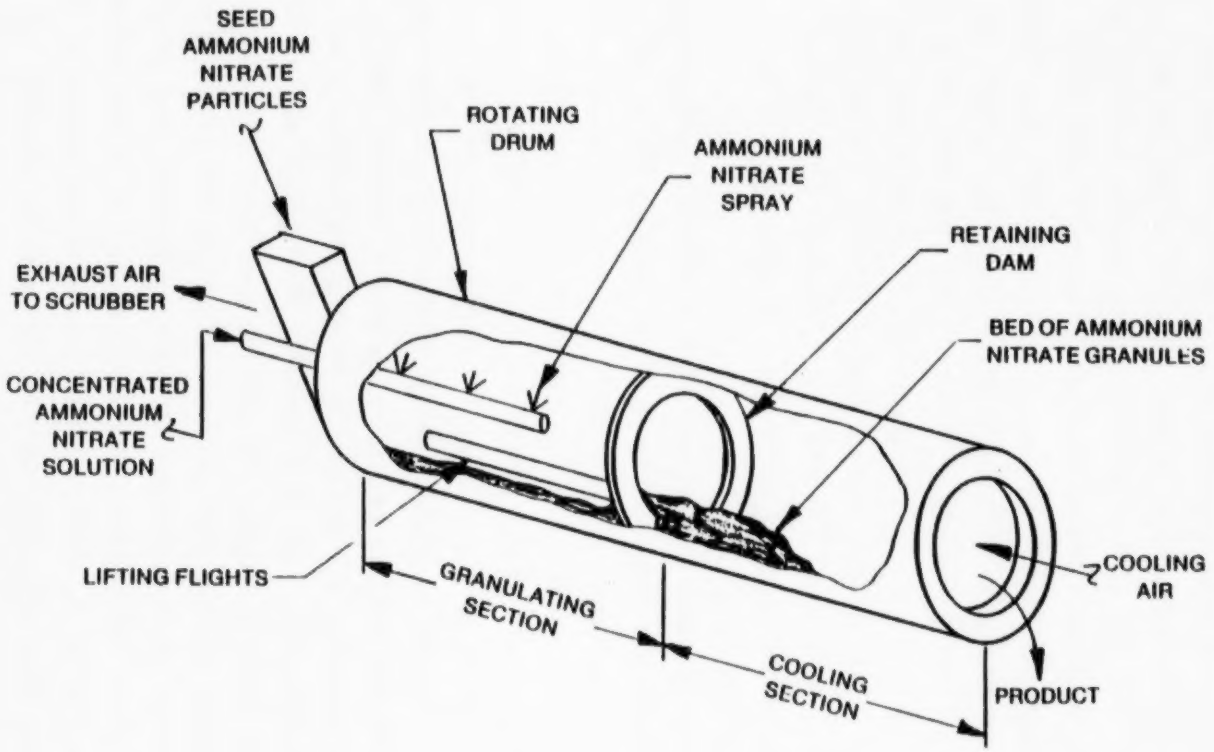

SEED AMMONIUM NITRATE PARTICLES
ROTATING DRUM
AMMONIUM NITRATE SPRAY
RETAINING DAM
BED OF AMMONIUM NITRATE GRANULES
EXHAUST AIR TO SCRUBBER
CONCENTRATED AMMONIUM NITRATE SOLUTION
LIFTING FLIGHTS
GRANULATING SECTION
COOLING SECTION
COOLING AIR
PRODUCT

Figure 3-10. Rotary drum granulator.

The granulation process can produce larger particles with greater abrasion resistance and about twice the crushing strength of standard prills, but their product is not as spherical or smooth as prills.[21] However, any range of product sizes, from smaller fertilizer grade granules to extra large forestry grade, can be manufactured in granulators. Different sizes are produced by varying the height of the retaining dam in the granulator, decreasing the contact time of the seed particles in the drum, choosing suitable screen sizes, or by using a combination of the above. A major disadvantage of granulators is that low density ammonium nitrate product cannot be manufactured economically using present technology.[22] A survey of industry indicated that there are six drum granulators operating at five different plants in the United States. All of these granulators are of the same design and operation.

Emission rates from drum granulators may be affected by the following:

(1) Number, design and location of lifting flights
(2) Airflow rates through the drum
(3) Recycle rate of seed material
(4) Rotation rate of the drum
(5) Crystal state changes of granules

The number, design and location of the lifting flights directly affect the emission rate. Flights lift and drop granules through the moving air stream to provide cooling of the particles; fine particles tend to become entrained in the air stream leaving the granulator. To reduce the entrainment of particles, some modifications have been made to existing drum granulators. These modifications involved changing the size and/or shape of the lifting flights or removing the lifting flights nearest the air discharge end of the granulator. These modifications are also being made on new installations.[23]

An increase in the airflow rate through the drum causes greater entrainment of small particles and increases emissions. An airflow velocity of approximately 1.2 meters/sec (4.0 ft/sec) appears to represent an optimum balance between cooling requirements and product loss.[24]

The recycle rate of seed material affects the bed temperature, and therefore, can affect emissions. Only a relatively narrow bed temperature range can be tolerated. An increase in seed material recycle rate will cool the bed, while a decrease will raise the bed temperature.[25] If the bed temperature increases significantly, and is maintained for several hours, the granules will turn to dust and increase emissions.[26]

An increase in the rotation rate of the drum increases the entrainment of AN in the airstream. Originally granulators were designed to rotate at 9 rpm, but because of excessive wear, the rate was reduced to 6 rpm, with no apparent effect on product quality.[27] However, once a suitable rotation rate is found, it is normally not changed, thus the rate of rotation is not considered a process variable.

As with prills, a rapid change in crystal state can cause the granules to break up into dust. This dust can become entrained in the airstream, increasing emissions.

Table 3-8 presents uncontrolled emissions from drum granulators. According to an EPA test, one drum granulator had uncontrolled ammonium nitrate emissions of 147.2 g/kg (294.6 lb/ton) of AN produced. The industry test data presented in Table 3-8 cannot be compared directly to EPA test data because of differences in sample collection and analysis procedures. However, the uncontrolled emission factors determined by industry are in close agreement with EPA's.

3.2.4.2 Pan Granulation. The pan granulator operates on basically the same principle as the drum granulator; it generates granules by adding successive layers of molten ammonium nitrate to seed particles.[29] The equipment consists of a large rotating circular pan tilted off the horizontal. Seed material (from offsize product recycle) deposited near the top of the pan, along with fine particles carried up by the rotating pan, pass through a fine spray of essentially anhydrous ammonium nitrate melt (see Figure 3-11). The newly sprayed particles roll to the bottom of the pan. As in the drum granulator, the smaller particles in the pan granulator sift toward the bottom of the granule bed on the lower part of the pan. Larger granules spill over the edge of the pan onto a

TABLE 3-8. UNCONTROLLED EMISSIONS FROM GRANULATORS[28]

Plant	Capacity		Ammonium Nitrate[c] Particulate		Ammonia[d]	
	Mg/day	Tons/day	g/kg	lb/ton	g/kg	lb/ton
Drum Granulation						
B[a]	381	420	147.2	295	29.7	59.5
K[b]	249	275	152	305	--	--
K[b]	352	388	138	277	--	--
Pan Granulation						
D[a]	325	358	1.34	2.68	0.07	0.15

[a] EPA test data.

[b] Reported by industry.

[c] $\frac{\text{g (lb) Ammonium Nitrate Emitted}}{\text{kg (ton) Ammonium Nitrate Produced}}$

[d] $\frac{\text{g (lb) Ammonia Emitted}}{\text{kg (ton) Ammonium Nitrate Produced}}$

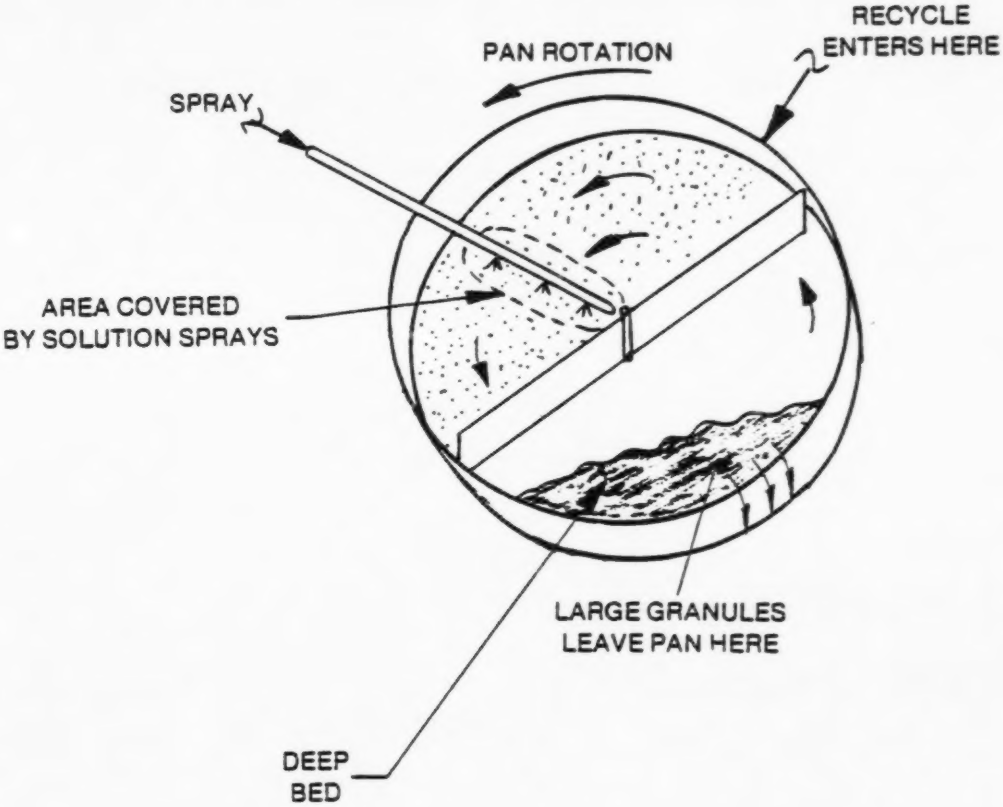

RECYCLE ENTERS HERE
PAN ROTATION
SPRAY
AREA COVERED BY SOLUTION SPRAYS
LARGE GRANULES LEAVE PAN HERE
DEEP BED

Figure 3-11. Top view of pan granulator.

conveyor belt and are removed for further processing. The pan granulator yields a product which is less spherical and somewhat softer than granules produced in a rotary drum.[30] Pan granulation also tends to have a larger recycle to product ratio than drum granulators because almost all the required bed cooling is accomplished by the cooled recycle particles.

Recycled material consists of undersized and oversized granules. Undersized granules are used as seed particles and the oversized material is either dissolved and used in solution formation or crushed and used as seed. The amount of crushed material used as seed is held to a minimum since this practice can lead to formation of agglomerates and weak granules.

Operational parameters which are critical to product quality include the concentration and temperature of the feed melt, the slope and rotational speed of the pan, the location of the sprays, and the amount, size and temperature of the recycle material.[31]

Emissions are affected by the following:

(1) Airflow rates over the pan
(2) Rotational speed of the pan
(3) Bed temperature
(4) AN melt spray
(5) Crystal state changes of granules

An increase in the airflow rate can affect emissions by entraining more fine particles and fume. However, there is very little airflow over the pan; consequently, entrainment of fine spray or seed granules is less than that encountered in drum granulation. Operating data indicate that less than 5 percent by weight of the product is entrained.[24]

The rotational speed of the pan can also affect emissions. A higher rotational speed increases attrition of the granules, thus increasing emissions.

The temperature of the bed affects granule temperature. If bed temperature increases significantly, granules will turn to dust and increase emissions.

AN melt spray conditions affect emissions through fuming and fine particle formation. Fine particles are formed when the spray strikes the bottom and splatters. This splatter quickly cools to form fine particles which increase emissions.

As with other solids, a rapid change in crystal state can cause the granules to break up into dust. This dust can become entrained in the air stream, increasing emissions.

A detailed discussion of tests conducted by EPA on a pan granulation facility is presented in Appendix A. Uncontrolled ammonium nitrate particulate emissions averaged 1.34 g/kg (2.68 lb/ton) of ammonium nitrate produced (Table 3-8).

3.2.5 Solids Finishing

The ammonium nitrate industry utilizes various combinations of solids finishing equipment to cool, dry, screen and coat the ammonium nitrate solid, depending on the particular solid product and its formation process. High density prills are cooled, screened and sometimes coated; low density prills are predryed, dryed, cooled, screened and coated; and drum granulated product is screened, cooled and may be coated. Pan granulated product can then either follow the same finishing sequence as drum granulators, or pass through a precooler after solids formation to aid in cooling. Tables 3-9, 3-10, and 3-11 present operating parameters for coolers, predryers and dryers, respectively. The EPA test results are presented in detail in Appendix A. Process equipment operation and emissions are discussed below.

3.2.5.1 General cooler/dryer equipment designs. Cooling and drying are usually conducted in rotary drums. In the finishing process, inlet air is either conditioned or introduced at ambient temperatures. The conditioning process uses heat exchangers to heat, cool, or dehumidify the air. Moisture removal in the low density prill is one of the most critical steps in producing the final desired prill. If moisture is not removed after prill formation, caking will result.[15] With the exception of an auxiliary air dehumidifier, heater or cooler, all rotary drums have the same physical configuration. Figure 3-12 presents the configuration

TABLE 3-9. COOLER OPERATING PARAMETERS[32]

Plant	Facility	Production Capacity Mg/day (tons/day)	Airflow scm/Mg (scf/ton)	Air Temperature K(°F) Inlet	Air Temperature K(°F) Outlet	Solid AN Temperature K(°F) Inlet	Solid AN Temperature K(°F) Outlet
A	High Density Rotary Drum Cooler	545 (600)	1496 (48,000)	283 (50)	339 (150)	372 (210)	313 (105)
M	High Density Rotary Drum Cooler	294 (324)	3281 (105,286)	300 (80)	354 (177)	389 (240)	316 (110)
H	High Density Rotary Drum Cooler	458 (504)	2811 (90,186)	291 (65)	339 (151)	357 (184)	331 (137)
I	High Density Rotary Drum Cooler	318 (350)	4535 (145,536)	283 (50)	365 (198)	397 (256)	311 (100)
N	High Density Rotary Drum Cooler	363 (400)	2333 (74,845)	283 (50)	-	372 (210)	305 (90)
N	High Density Fluidized Bed Cooler	363 (400)	6065 (194,593)	283 (50)	-	372 (210)	305 (90)
T	High Density Fluidized Bed Cooler	872 (960)	1223 (39,241)	280 (45)	294 (70)	363 (194)	324 (124)
B	Rotary Drum Granulator Rotary Drum Cooler	454 (500)	1800 (57,670)	-	-	330 (135)	307 (93)
E	Rotary Drum Granulator Rotary Drum Cooler	277 (305)	2150 (68,930)	-	332 (138)	324 (124)	300 (81)
K	Rotary Drum Granulator Rotary Drum Cooler	272 (300)	1940 (62,050)	282 (48)	308 (95)	333 (140)	303 (86)
K	Rotary Drum Granulator Fluidized Bed Cooler	363 (400)	2770 (88,720)	299 (79)	312 (102)	333 (140)	305 (90)
D	Pan Granulator Rotary Drum Precooler	320 (353)	3200 (102,400)	-	-	-	-
D	Pan Granulator Rotary Drum Cooler	314 (346)	1610 (51,610)	-	-	-	-
C	Low Density Rotary Drum Cooler	194 (214)	1620 (51,900)	281 (47)	328 (130)	345 (162)	306 (91)
H	Low Density Rotary Drum Cooler	457 (504)	2700 (86,380)	303 (85)	317 (111)	334 (142)	308 (95)
J	Low Density Rotary Drum Cooler	453 (499)	1440 (46,150)	289 (60)	316 (110)	333 (140)	304 (88)
L	Low Density Rotary Drum Cooler	409 (451)	1740 (55,850)	278 (40)	316 (110)	322 (120)	304 (88)
L	Low Density Rotary Drum Cooler	409 (451)	4150 (133,100)	278 (40)	316 (110)	322 (120)	304 (88)
Q	Low Density Rotary Drum Cooler	272 (300)	2250 (72,000)	294 (70)	325 (125)	347 (165)	316 (110)
F	Low Density Fluidized Bed Cooler	222 (245)	3320 (106,330)	291 (65)	308 (95)	333 (140)	308 (95)
Z	Low Density Fluidized Bed Cooler	582 (641)	4281 (137,281)	-	-	-	-

TABLE 3-10. LOW DENSITY PREDRYER OPERATING PARAMETERS[a] 33

Plant	Capacity, Mg/day (TPD)	Prill Temperature, K (°F)		Prill Moisture wt percent H_2O		Prill Residence Time, Minutes	Air Temperature K (°F)		Air Flow Rate dscm/Mg (dscf/ton)
		Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	
C	194 (214)	331 (137)	350 (170)	-	-	-	378 (220)	343 (158)	1560 (49,840)
F[b]	222 (245)	353 (175)	344 (160)	3.5	2.6	20	350 (170)	350 (170)	3310 (106,000)
H	457 (504)	345 (162)	344 (159)	2.5	1.5	10	336 (145)	345 (161)	2570 (82,380)
J	453 (499)	366 (200)	355 (180)	3.0	1.8	20	366 (200)	344 (161)	1130 (36,060)
L	409 (451)	350 (170)	366 (145)	2.5	1.4	30	355 (180)	322 (120)	1400 (45,000)
L	409 (451)	350 (170)	336 (145)	2.5	1.4	30	355 (180)	322 (120)	1790 (57,450)
Q	272 (300)	350 (170)	339 (150)	3.5	2.5-3.0	13	366 (200)	339 (150)	2250 (72,000)
Z	479 (528)	-	-	-	-	-	-	-	3263 (104,649)

[a] All predryers are rotary drum except as noted.

[b] Fluidized bed

TABLE 3-11. LOW DENSITY PRILL DRYER OPERATING PARAMETERS[a] [34]

Plant	Capacity, Mg/day (TPD)	Prill Temperature, K (°F)		Prill Moisture wt percent H_2O		Prill Residence Time, Minutes	Air Temperature K (°F)		Air Flow Rate dscm/Mg (dscf/ton)
		Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	
C	194 (214)	350 (170)	345 (162)	-	-	-	370 (206)	345 (161)	1450 (46,410)
F[b]	222 (245)	344 (160)	333 (140)	2.6	1.6	20	333 (140)	333 (140)	3480 (111,300)
H	457 (504)	344 (159)	334 (142)	1.5	0.3	10	330 (135)	330 (139)	2800 (89,600)
J	453 (499)	355 (180)	333 (140)	1.8	0.4	20	366 (200)	333 (140)	1080 (34,620)
L	409 (451)	336 (145)	322 (120)	1.4	0.4	30	355 (180)	322 (120)	1990 (63,830)
L	409 (451)	335 (145)	322 (120)	1.4	0.4	30	355 (180)	322 (120)	4240 (136,000)
Q	272 (300)	339 (150)	316 (110)	2.8	0.9	13-23	353 (175)	314 (105)	2250 (72,000)
Z	479 (528)	-	-	-	-	-	-	-	2942 (94,324)

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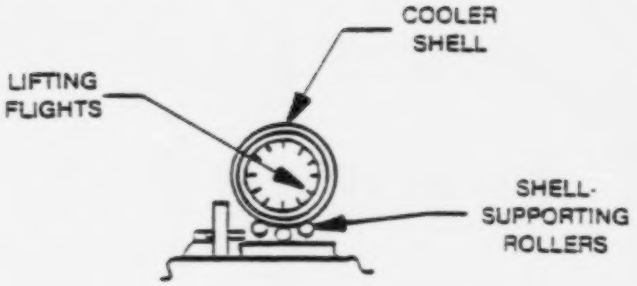
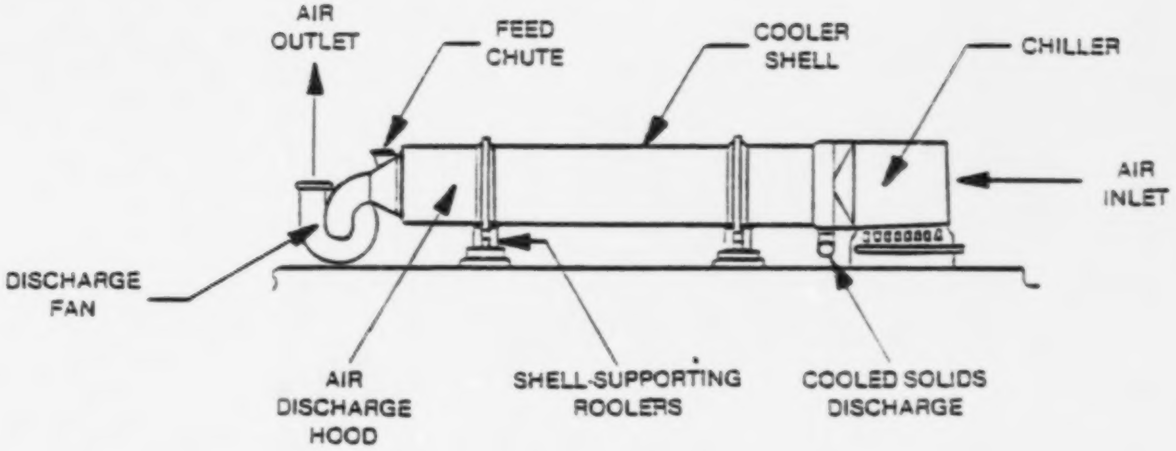
[a] All dryers are rotary drum except as noted.

[b] Fluidized bed


COOLER SHELL
LIFTING FLIGHTS
SHELL-SUPPORTING ROLLERS

END VIEW


AIR OUTLET
FEED CHUTE
COOLER SHELL
CHILLER
AIR INLET
DISCHARGE FAN
AIR DISCHARGE HOOD
SHELL-SUPPORTING ROOLERS
COOLED SOLIDS DISCHARGE

SIDE VIEW

Figure 3-12. Rotary drum cooler.

for a rotary drum cooler. A rotating inclined shell is supported on two sets of rollers and driven by gear and pinion. At the upper end is the feed chute which brings in material. Flights, welded along the inside of the shell, lift the material being dryed or cooled and shower it down through the flow of air. The product is discharged onto a conveyor at the lower end of the drum. Just beyond the discharge end of the rotary drum is a set of heat exchangers which treat incoming air. The airflow, which is countercurrent to the product flow, is supplied by an induced draft fan which keeps the system under a slight vacuum. The fan suction is connected to a hood at the upper end of the drum and the fan discharges through a stack to the atmosphere or to an emission control device. Emissions from rotary drum dryers or coolers consist of fine particulates that have eroded from the product and become entrained in the discharged air stream.

The following design and process parameters affect emissions from rotary drum coolers and dryers:

(1) Number, design and location of lifting flights
(2) Speed of drum rotation
(3) Air flowrate through the drum
(4) Temperature of product

Rotary drum dryers, predryers and coolers operate in much the same manner as the cooling section of drum granulators; therefore, design and operating parameters affect emissions in similar ways. Both drum rotation speed and design of the lifting flights affect emissions. As the lifting flights lift and drop the solids through the moving air stream, fine particles tend to become entrained in the air stream, creating emissions. Modifications are often made to the shape, size and location of the lifting flights in order to reduce emissions. Also, the rotation of the drum can erode the particles, causing a larger number of fines which increases emissions. Drum rotation speed is not considered to be a process variable and is rarely changed once a suitable rate has been found.

The airflow rate through the drum affects emissions, also. Higher airflow rates can increase the amount of fines entrained in the air stream.

Prill and granule temperature control is necessary to control emissions. Changes in specific volume of the solid accompany changes in crystal structure, which is a function of the solid temperature. Changes in specific volume may contribute to solid AN disintegration. With low density prills especially, the change in specific volume increases emissions through the creation of additional fines.[34] Also, the bed temperature in the rotary drum cooler can affect emissions indirectly. Higher bed temperatures require increased airflow rates to cool the prills. And, as discussed above, higher airflow rates can cause greater emissions.

Fluidized bed cooling units are also used on drum granulated and prilled products. A fluidized bed cooler consists of a long narrow vessel separated into two parts by a horizontal perforated plate (the bed plate). Conditioned air is blown up through the bed plate to fluidize the prills or granules in the upper half of the vessel. Hot prills or granules drop onto the inclined end of the long plate, and displace the fluidized particles along the bed causing the cooled material to spill over the opposite end into the outlet chute, as shown in Figure 3-13.[35]

The advantages of a fluidized bed cooler are that the capital cost, size, and weight are lower than for a rotary drum; also, no special foundations are needed and there is no product abrasion on moving parts. An additional advantage is that the residence time in the unit is much shorter than for a comparable rotary unit. It is also reported that the flow of the fluidizing air can be adjusted so that fines are left in the product or removed for collection and treatment.[36]

Of the two AN plants constructed during the last ten years, both have employed fluidized bed coolers in their processes. However, there is insufficient information to conclude that this is an industry trend.

3.2.5.2 High Density Prill Cooling. Because of low moisture content, high density prills only require cooling when they exit the

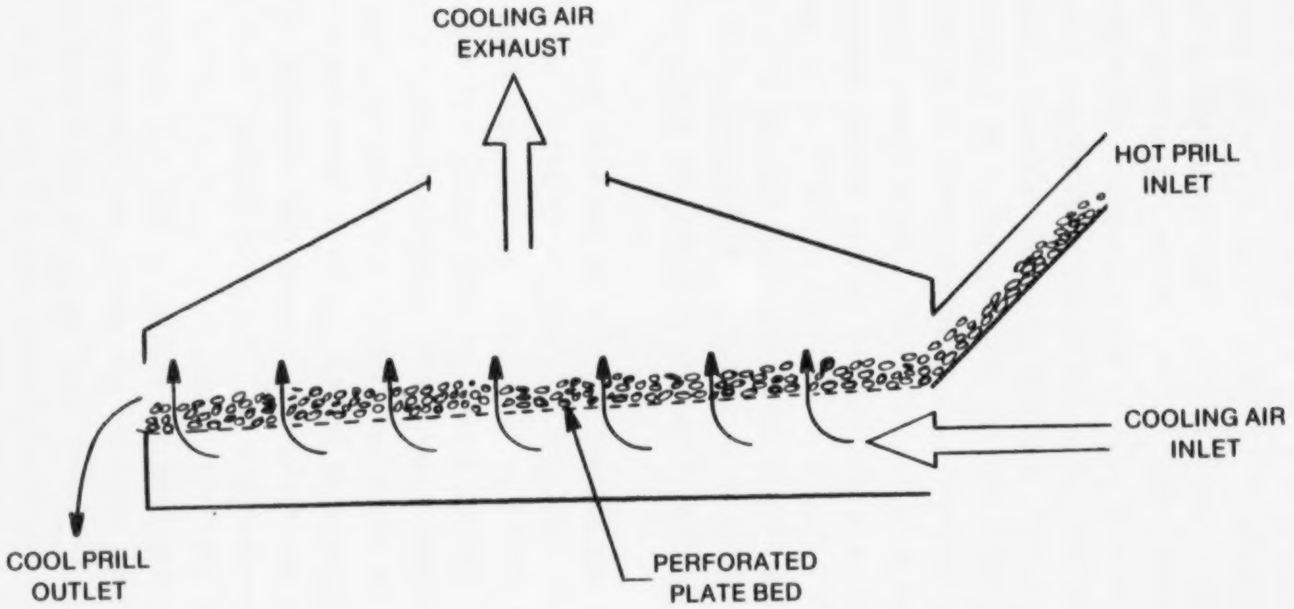

COOLING AIR EXHAUST
HOT PRILL INLET
COOLING AIR INLET
COOL PRILL OUTLET
PERFORATED PLATE BED

Figure 3-13. Fluidized bed cooler.

prill tower. The prills are usually belt conveyed from the prill tower, at temperatures of 358 to 389 K (185 to 240°F), to a rotary drum cooler. Internal flights in the cooler lift the prills and cause them to fall through a countercurrent airflow. The prills have a residence time of 8 minutes to approximately 1 hour in the rotary drum cooler depending on design.[37] Prills are usually cooled to between 305 and 331 K (90 and 137°F) and have a moisture content between 0.2 and 0.5 percent by weight (Table 3-9).[37] Airflow rates are reported between 1,496 and 4,535 scm/Mg (48,000 and 145,536 scf/ton) of AN produced. Some plants report varying the airflow through the cooler to maintain product outlet temperature at desired levels, while others report varying product throughput rate to obtain desired product outlet temperature.[38,39,40] The cooling air gains 50 to 88 K (90 to 160°F) as it passes through the cooler.[37] EPA emissions data for a high density prill rotary drum cooler are presented in Table 3-12. The results of EPA testing indicate that ammonium nitrate is emitted at a rate of 0.8 g/kg (1.6 lb/ton) of AN produced.

Fluidized bed coolers are used at two high density prill plants. Inlet cooling air is reportedly chilled to 280 K (45°F) at one plant and to about 283 K (50°F) at the other. One of these fluidized bed coolers, which operates with an airflow of 6065 scm/Mg (194,593 scf/ton) of AN produced, reportedly lowers prill temperature from 372 K (210°F) to 305 K (90°F). No emissions data are available for these units.

3.2.5.3 Granulated product cooling. Both rotary drum and fluidized bed coolers are employed to cool granulated ammonium nitrate, but rotary drums are most commonly used. The units operate identically to coolers in high density prilling plants.

Emissions data from EPA testing of two drum granulator coolers and one pan granulator precooler and cooler are presented in Table 3-12. Ammonium nitrate emissions from the (drum granulator) coolers are reported to be 7.5 g/kg (15 lb/ton) and 8.6 g/kg (17.3 lb/ton) of AN produced. Ammonium nitrate emissions from the finishing equipment for the pan granulator were found to be 18.0 g/kg (36.0 lb/ton) of AN produced

TABLE 3-12. UNCONTROLLED EMISSIONS FROM COOLERS[a] [41]

Plant	Facility	Ammonium nitrate particulate[b]		Ammonia[c]	
		g/kg	(lb/ton)	g/kg	(lb/ton)
A	High density rotary drum cooler	0.8	(1.6)	0.02	(0.05)
B	Rotary drum granulator Rotary drum cooler	7.5	(15.0)	0	0
E	Rotary drum granulator Rotary drum cooler	8.6	(17.3)	1.18	(2.35)
D	Pan granulator Rotary drum precooler	18.0	(36.0)	0	0
D	Pan granulator Rotary drum cooler	0.25	(0.49)	0	0
C	Low density rotary Drum cooler	12.3	(24.5)	0	0
L[d]	Low density rotary Drum cooler	19.2	(38.4)	--	--
L[d]	Low density rotary Drum cooler	35.5	(70.5)	--	--
Z	Low density fluidized Bed cooler	37.8	(75.7)	0.29	(0.59)

[a] All data is EPA test data unless otherwise noted.

[b] $\frac{\text{g(lb) Ammonium Nitrate Emitted.}}{\text{kg(ton) Ammonium Nitrate Produced.}}$

[c] $\frac{\text{g(lb) Ammonia Emitted.}}{\text{kg(ton) Ammonium Nitrate Produced.}}$

[d] Industry test data.

for the precooler and 0.25 g/kg (0.49 lb/ton) of AN produced for the cooler. A discussion of the testing can be found in Appendix A.

Operating information on three rotary drum coolers and one fluidized bed cooler is presented in Table 3-9. In rotary drum coolers, the granule temperature decreases an average of 25 K (46°F). Reported airflows are 1800 scm/Mg (57,670 scf/ton), 1940 scm/Mg (62,050) and 2150 scm/Mg (68,930 scf/ton) of AN produced. For the fluidized bed cooler, inlet air is cooled to an average temperature of 299 K (78°F). The fluidized bed cooler operates with an airflow of 2770 scm/Mg (88,720 scf/ton) of AN produced and lowers the ammonium nitrate granule temperature from 333 K (140°F) to 305 K (90°F). The temperature of the cooling air increases approximately 13 K (23°F). Residence time of the granules in this cooler is approximately one minute.

3.2.5.4 Low density prill predrying, drying, and cooling. Low density prills initially have a higher water content than high density prills. To remove this water, low density prills are dried in three steps: predrying, drying and cooling. Although cooling is not usually associated with the removal of moisture, ammonium nitrate coolers do achieve a small amount of final water removal. These steps are normally conducted in three separate rotary drums, although one plant (Plant F) reports the use of three separate fluidized beds. Tables 3-9, 3-10 and 3-11 summarize available information on the operation of coolers, predryers, and dryers, respectively.

Industry reports that the key parameters monitored to control predryer, dryer or cooler operations are prill temperature and prill moisture into and out of the units, and air temperature into and out of the units.[42,43] Plants can control either the airflow rate or the air temperature to control prill temperature and moisture. Fluidized bed units generally control airflow rate and rotary drum units generally control air temperature.[44,42] The quantitative effect of these parameters on uncontrolled emissions is not known. However, changes in these and other parameters can lead to increased emissions, as discussed in Section 3.2.5.1.

The information in Table 3-10 indicates that between 26 and 44 percent of the moisture in the prills is removed in the predryer. Residence time of the prills in the predryer are reported to be between 10 and 30 minutes. The average predryer is fed low density prills at a temperature of 349 K (169°F) and the prill temperature is reduced to an average of 343 K (158°F) at the exit. Two notable exceptions to the average are apparent. Plant C reports that the prill temperature increases 19 K (33°F) in passing through the predryer, and Plant J reports that prills enter the predryer at 366 K (200°F) and exit the predryer at 355 K (180°F).

In Table 3-10, reported airflows vary from 1130 to 3310 dscm/Mg (36,060 to 106,000 dscf/ton) of AN produced for rotary drum predryers. The airflow rates are varied, depending on the desired product outlet temperature, inlet air temperature and product throughput rate. Results of EPA testing indicate that the uncontrolled AN emissions from two low density rotary drum predryers are 10.1 g/kg (20.2 lb/ton) and 37.3 g/kg (74.6 lb/ton) of AN produced. Results of EPA tests and industry tests on predryers are presented in Table 3-13.

After predrying, prills are conveyed to a dryer for further drying. From Table 3-11, it can be seen that between 38 and 80 percent (average 58.5 percent) of the moisture in the entering prills is removed in the dryer. Residence time is between 10 and 30 minutes. The average dryer shows a reduction in prill temperature from 343 K (158°F) to 329 K (133°F). Reported airflows vary from 1080 to 4240 dscm/Mg (34,620 to 136,000 dscf/ton) of AN produced and are varied depending on the desired product outlet temperature, inlet air temperature and product throughput rate. Uncontrolled emissions from EPA and industry source tests on low density rotary drum dryers are presented in Table 3-14. Results of EPA tests show uncontrolled AN emissions from two low density rotary drum dryers of 11.4 g/kg (22.8 lb/ton) and 93.7 g/kg (187.4 lb/ton) of AN produced.

After drying, prills are conveyed to a cooler which also removes some moisture from the prills. Low density prills leaving the cooler

TABLE 3-13. UNCONTROLLED EMISSIONS FROM LOW DENSITY ROTARY DRUM PREDRYERS[a] [41]

Plant	Ammonium Nitrate particulate[b]		Ammonia[c]	
	g/kg	(lb/ton)	g/kg	(lb/ton)
C	10.1	(20.2)	0	0
Z[d]	37.3	(74.6)	0.29	(0.58)
L_1[e]	3.2	(6.4)	--	--
L_2[e]	4.1	(8.2)	--	--

---

[a] All data is EPA test data unless otherwise noted.

[b] $\frac{\text{g(lb) Ammonium Nitrate Emitted.}}{\text{kg (ton) Ammonium Nitrate Produced.}}$

[c] $\frac{\text{g(lb) Ammonia Emitted.}}{\text{kg (ton) Ammonium Nitrate Produced.}}$

[d] Emissions are based on a combined predryer and dryer the predryer constitutes 22 percent of the emissions by weight.

[e] Industry test data.

TABLE 3-14. UNCONTROLLED EMISSIONS FROM LOW DENSITY ROTARY DRUM DRYERS[a41]

Plant	Ammonium nitrate particulate[b]		Ammonia[e]	
	g/kg	(lb/ton)	g/kg	(lb/ton)
C	11.4	(22.8)	0	0
Z[d]	93.7	(187.4)	1.3	(2.6)
L_1^e	22.9	(45.7)	--	--
L_2^e	7.8	(15.6)	--	--

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[a] All data is EPA test data unless otherwise noted.

[b] g(lb) Ammonium Nitrate Emitted.
kg(ton Ammonium Nitrate Produced.

[c] g(lb) Ammonia Emitted.
kg (ton) Ammonium Nitrate Produced.

[d] Emissions are based on a combined predryer and dryer outlet of which the dryer constitutes 88 percent of the emissions by weight.

[e] Industry test data.

contain between 0.13 and 0.4 percent (average 0.21 percent) moisture by weight.[45] The average cooler is fed low density prills at 333 K (141°F) and cools the prills to an average of 307 K (93°F) (Table 3-9). Residence time in the cooler varies between 10 and 30 minutes.[45] Reported airflows range between 1440 and 4281 dscm/Mg (46,150 and 137,281 dscf/ton) of AN produced and are changed depending on the desired product outlet temperature, inlet air temperature and product throughput rate. Test results on coolers are presented in Table 3-12. Results of EPA test results show uncontrolled AN emissions from a low density rotary drum cooler of 12.3 g/kg (24.5 lb/ton) of AN produced and from a low density fluidized bed cooler of 37.8 g/kg (75.7 lb/ton) of AN produced.

3.2.6 Screening

Screening operations separate offsize ammonium nitrate solids from the properly sized product. In low and high density prilling plants, offsize material from the screens is redissolved in water or a weak solution of ammonium nitrate, then recycled to the solution formation process. In granulation plants, undersized and oversized granules (the oversized are first crushed) from the screens are returned to the granulator as seed material or returned to the solution formation process.

Shaking and vibrating screens are most commonly used in the ammonium nitrate manufacturing industry. Shaking screens consist of a rectangular frame with perforated plate or wire cloth screening surfaces, usually suspended by rods or cables and inclined at an angle of about 15 degrees.[46] Vibrating screens have one or more decks, usually planar. The screen forms the floor of a box which is vibrated mechanically or electrically. The ammonium nitrate particles vibrate normal to the screen surface.

Emissions are generated by the attrition of the ammonium nitrate solids against the screens and against one another. Therefore, almost all screening operations used in the ammonium nitrate manufacturing industry are enclosed or have a cover over the uppermost screen. The screening equipment is located inside a building and emissions are ducted from the process. Results of the survey conducted during this program indicate that this operation is a small emission source, and in most cases no visible emissions were observed.

3.2.7 Coating and Additives

Solid prills and granules are usually treated to prevent them from becoming moist and caking. In some cases additives are injected into the melt for this purpose. Another alternative is to coat the solids with kaolin, talc or diatomaceous earth. Both additives and coatings serve a similar purpose. Some plants even utilize both processes when treating solids. Of thirteen high density prilling plants surveyed, four plants coat the prills, five plants use both an additive and a coating, and four plants use an additive. Of seven low density prilling plants surveyed, all report the use of a coating.[47]

A survey of the industry indicates that the type of coating material affects the final product composition. The final product contains about 0.15 to 1.5 weight percent of coating when using talc, about 1.1 weight percent when using kaolin, and about 1 to 3 weight percent when using diatomaceous earth.[48]

Prills and granules are typically coated in a rotary drum coater. The rotating action produces a uniformly coated product. The mixing action also causes some of the coating material to be suspended in air, thus creating particulate emissions. However, drums are typically maintained at a slight negative pressure and the emissions are vented to a particulate control device. Any dust captured is usually recycled to the coating storage bins. Industry sources estimate uncontrolled emissions from the coater to range from 0.5 to 3.0 g/kg (1.0 to 6.0 lb/ton) of ammonium nitrate produced.[49]

3.2.8 Bagging

Only a small fraction of the total solid ammonium nitrate produced is bagged (approximately 10 percent).[6] Bagging operations are a source of particulate emission. Two types of bags commonly used for bagging are the open-top, sewn bag and the corner-fill, valve-type bag. The open-top bag is held under a bagging machine which fills the bag to a predetermined weight. After filling, the top is pinched together and sealed. The corner-fill, valve bag is "factory closed"; that is, the top and bottom are closed either by sewing or by pasting, and a small single opening or valve is left on one corner. Ammonium nitrate is discharged into a bag through the valve, which closes automatically due to the back pressure produced by the contents of the bag. Dust is emitted from each bagging method during the final stages of filling when dust-laden air is displaced from the bag by the ammonium nitrate. The potential for emissions during bagging is greater for coated material than for uncoated material. Data are not available on emission quantities (controlled or uncontrolled) from bagging operations. It is expected that emissions from bagging operations consists primarily of the kaolin, talc or diatomaceous earth coating materials.

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4.0 EMISSION CONTROL TECHNIQUES

This chapter discusses techniques for controlling particulate emissions from manufacturing processes in the ammonium nitrate (AN) industry. Section 4.1 briefly reviews particulate control devices currently in use. Section 4.2 presents a general description of each emission control technique used in the industry and a discussion of the design variables and factors affecting their performance. Emission test data for each of the sources being considered in detail in this document are presented in Section 4.3. Discussion of the test results and expected control device performance in the ammonium nitrate industry are presented in Section 4.4.

4.1 OVERVIEW OF CONTROL TECHNIQUES

The selection of a control device depends upon several factors, including the source of emissions, the physical and chemical properties of the particulate, and the characteristics of the exhaust stream containing the particulate. The ammonium nitrate industry uses fabric filters and a variety of wet scrubbers for particulate removal.

Fabric filters are not used for controlling emissions from solids formation process equipment (prill towers and granulators) or solids finishing process equipment (predryers, dryers, and coolers). The hygroscopic nature of ammonium nitrate particulates, combined with the moisture content of the gas streams, cause blinding of the filter. However, fabric filters are used to control particulate emissions from bagging and coating operations which deal with the finished dried product.

Wet scrubbers are the predominate particulate emission control device used in the ammonium nitrate industry. This is because scrubber wastewater containing recovered ammonium nitrate can be readily utilized as a fertilizer solution or reintroduced into the solution process. Also, wet scrubbers are less subject to caking by hygroscopic materials.

Table 4-1 presents a summary of emission control devices currently used on the emission sources under consideration in this document. The following subsections briefly describe these devices.

4.1.1 High Density Prill Towers

Twelve high density prill towers currently use collection hoods in conjunction with wet scrubbers. The wet scrubber only treats the air captured by the collection hood, which is usually 20 to 25 percent of the total prill tower airflow. One high density prill tower, although equipped with a hood and bypass, does not bypass and treats the full tower airflow. The tower airflow, in this case, is reduced by process modifications. Eleven of these thirteen towers, including the one that treats the full flow, use a wetted fibrous filter scrubber. Of the remaining two towers, one uses a venturi scrubber and the other uses a wetted mesh pad. Pressure drops for the wetted fibrous filter scrubbers range from 1.50 to 6.5 kPa (6 to 26 in. W.G.).[1] No information is available on the operation of the venturi scrubber or the wetted mesh pad.

Four high density prill towers treat total tower airflow with low efficiency scrubbers. These scrubbers include one valve-tray scrubber, two spray tower scrubbers equipped with a wetted mesh pad, and a knockout chamber. The valve tray scrubber operates at a pressure drop of 2.7 kPa (10.7 in. W.G.) and the spray tower scrubbers have a pressure drop of 0.5 kPa (2 in. W.G.).[2,3] No information is available on the operation of the knockout chamber.

4.1.2 Low Density Prill Towers. Twelve of eighteen plants which produce low density prills do not control their prill tower emissions. However, five low density facilities employ collection hoods in conjunction with a wetted fibrous filter scrubber. Pressure drops for these scrubbers are reported to range from 1.50 to 6.5 kPa (6 to 26 in. W.G.).[1] One low density prill tower treats total tower airflow with an impingement type scrubber operating at a pressure drop of 0.75 kPa (3 in. W.G.).[4]

TABLE 4-1. EMISSION CONTROL TECHNIQUES USED BY THE AMMONIUM NITRATE INDUSTRY[5]

			Wet Scrubbers								Other Controls		
Process	Facility	Number of Sources Included in Survey	Fibrous Filter	Entrainment	Cyclone	Venturi	Tray	Mechanical	Other[b]	None	Fabric Filter	Dry Cyclone	No. Info.
Solids Formation	High Density Prill Tower	20	12[a]	-	-	1	1	-	3	3	-	-	-
	Low Density Prill Tower	18	5	1	-	-	-	-	-	12	-	-	-
	Drum Granulator	6[c]	-	8	-	-	-	-	-	-	-	-	-
	Pan Granulatcr	1	-	-	-	1	-	-	-	-	-	-	-
Solids Finishing	Predryer, Dryer or cooler	76[d]	1	7	37	-	7	12	2	3	-	-	3

[a] Eleven of these scrubbers are fibrous filters and one is a wetted mesh pad.

[b] Includes knockout chambers, spray towers, etc.

[c] Two of the drum granulators have two entrainment scrubbers each.

[d] Total number of solids finishing processes with available data. Some will have more than one control device or may be connected in series to a single control device.

4.1.3 Rotary Drum Granulators and Pan Granulators

At present, all rotary drum granulators are controlled by entrainment scrubbers. These scrubbers typically operate with pressure drops of 3.5 kPa (14 in. W.G.).[6]

The one commercial pan granulator in operation is controlled by a venturi scrubber with a pressure drop of 6.8 kPa (27 in. W.G.).[7]

4.1.4 Solids Finishing Processes

Solids finishing equipment includes rotary drum predryers, dryers, coolers and fluid bed coolers. A variety of scrubber types are used, but wet cyclone scrubbers are the most common. Pressure drops for these scrubbers range from 0.5 - 1.5 kPa (2-6 in. W.G.).[8] Mechanically aided scrubbers are the second most used scrubber. These scrubbers have a variety of designs, but all have a fan to aid in particulate removal and operate at pressure drops very similar to those for the wet cyclones. Other scrubbers in use include entrainment scrubbers and tray-type scrubbers.

4.2 DESCRIPTION OF CONTROL TECHNIQUES

The following subsections present a detailed description of emission collection and control devices applicable to the ammonium nitrate industry. In addition, the sections provide a summary of their basic operating principles and a discussion of the factors affecting the performance of each device.

4.2.1 Fume Collection Hoods

Fume collection hoods are applied exclusively to prill towers. As discussed in Chapter 3, prill tower emissions occur due to a variety of processes, including fuming, microprill formation during jet breakup, and prill fragmentation. Microprill formation and fuming occur in the vicinity of the droplet forming device. The function of collection hoods (Figure 4-1) is to capture these emissions by surrounding the spray head or bucket in the prill tower and ducting the emissions to a scrubber. Approximately 40 to 90 weight percent of total prill tower emissions are reportedly captured in an air stream representing 15 to 30 percent of the tower airflow (Table 4-2). The collection hood reduces

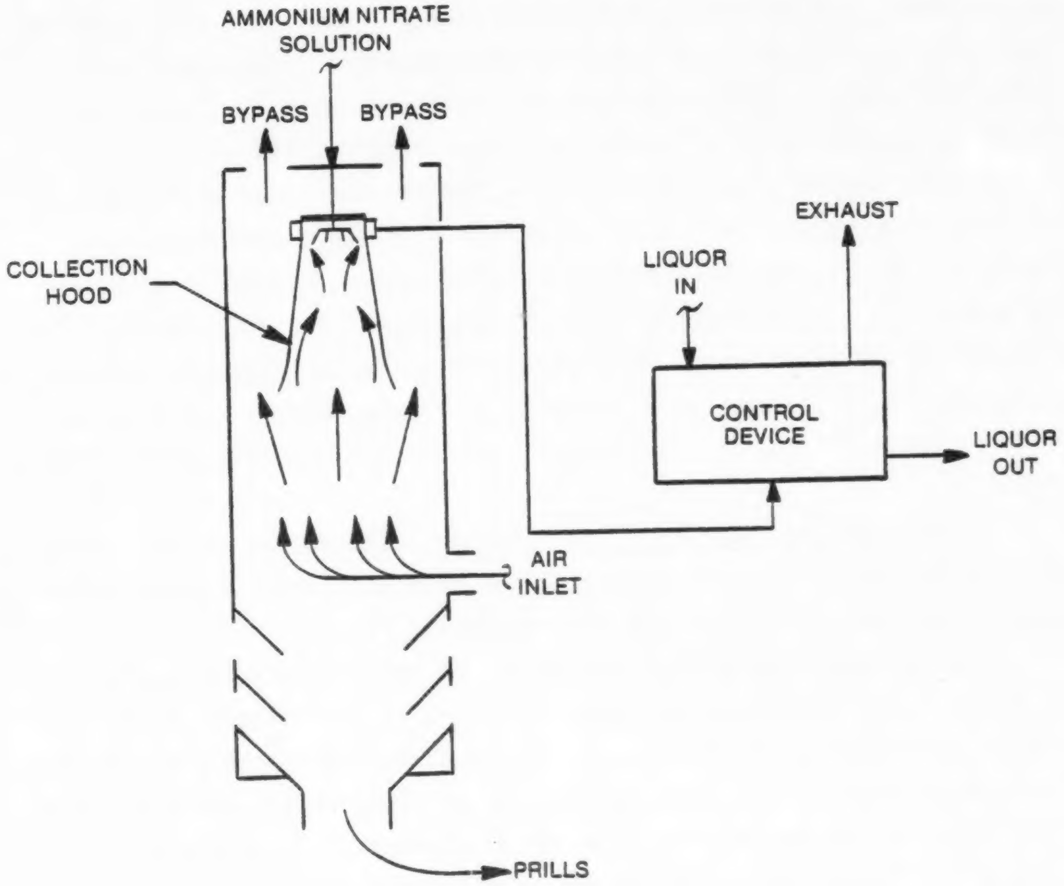
AMMONIUM NITRATE SOLUTION
BYPASS
BYPASS
EXHAUST
COLLECTION HOOD
LIQUOR IN
CONTROL DEVICE
LIQUOR OUT
AIR INLET
PRILLS

Figure 4-1. Prill tower / collection hood configuration.

the amount of air requiring treatment, thus reducing the size of the prill tower control apparatus. The major portion of the prill tower airflow bypasses the collection hood and is vented to the atmosphere untreated. Any of the following particulate scrubbers can be used in conjunction with fume collection hoods.

4.2.2 Wet Scrubbing

A wet scrubber is a device in which a particle laden gas stream is brought into contact with a liquid for the purpose of transferring particulates from the gas to the liquid stream. There are many different types of scrubbers and many different techniques to bring about the gas/liquid contact. Consequently, wet scrubbers exhibit a broad range of costs, collection efficiencies and power requirements.

The following subsections briefly describe the types of scrubbers and typical operating parameters encountered in the ammonium nitrate industry. In the sections below, the cut diameter is used to describe and compare the performance of various scrubbers. The cut diameter of a scrubber is the diameter of the particle that the scrubber will collect at 50 percent efficiency. For example, a scrubber with a cut diameter of 2 microns will remove particles of 2 microns in diameter at 50 percent efficiency.

4.2.2.1 Wetted Fibrous Filter Scrubber. The wetted fibrous filter scrubber is typically used in conjunction with a collection hood, but it can also be used to control the entire exhaust flow.

This scrubber consists of two series of filter elements separated by an atomizing spray chamber (see Figure 4-2). Each filter element, made of compressed glass fibers, is irrigated to remove captured particles. The exhaust stream first encounters a set of elements of relatively low fiber density, designated "spray catcher" elements. These elements collect the large, insoluble particulates (larger than 3 microns) that may clog the second set of filter elements. According to the manufacturer's literature, the dominant collection mechanism for these elements is inertial impaction.[9] The pressure drop across the "spray catcher" elements is 0.25 to 0.50 kPa (1 to 2 in. W.G.).

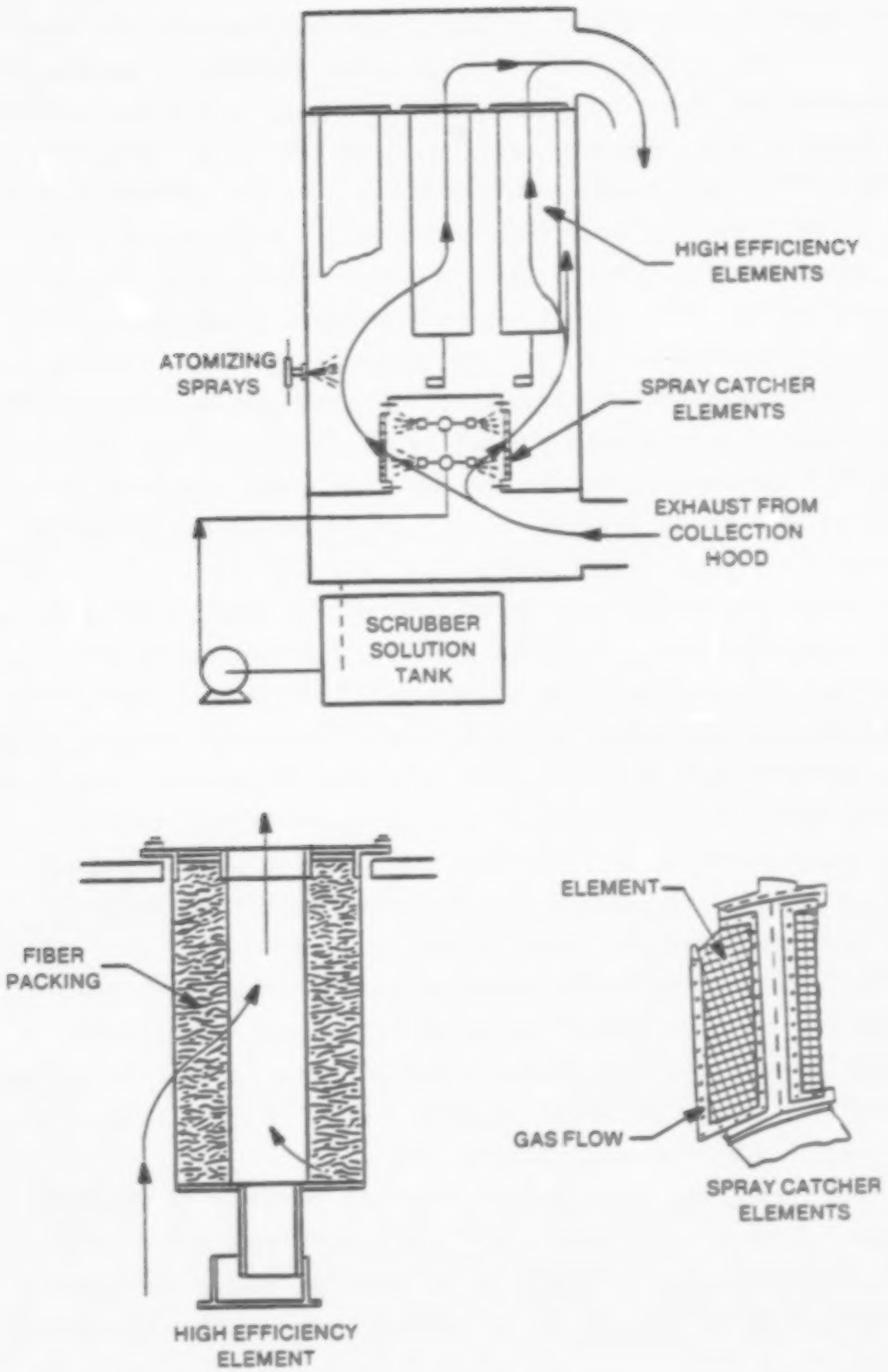
HIGH EFFICIENCY ELEMENTS
ATOMIZING SPRAYS
SPRAY CATCHER ELEMENTS
EXHAUST FROM COLLECTION HOOD
SCRUBBER SOLUTION TANK
FIBER PACKING
HIGH EFFICIENCY ELEMENT
ELEMENT
GAS FLOW
SPRAY CATCHER ELEMENTS

Figure 4-2. Detail of a wetted fibrous filter scrubber.[10,11]

The remaining particulates in the gas stream flow into the spray chamber where some of them impinge on the water droplets. The particle laden droplets are then removed from the gas stream by the second set of filter elements, which are designated as "high efficiency" elements. These high efficiency elements contain fibers that are compressed to a greater density than the spray catcher elements. The pressure drop across these elements is about 1 to 5 kPa (4 to 20 in. W.G.) for prill tower applications. The manufacturer's literature states that the dominant collection mechanism for these elements is Brownian movement of the particles. Brownian movement causes the particles to collide with the glass fiber mat where they are collected.[12] A collection efficiency of 95 to 99.5 percent is reported for particles under 3 microns in diameter, as well as 100 percent collection efficiency for particles larger than 3 microns. (See Figure 4-3).

The major factor affecting performance of the wetted fibrous filter scrubber is airflow rate. As stated earlier, the two filters have different particle collection mechanisms and capabilities. Because of these differences, the effect on collection efficiency of changes in gas airflow, particle concentration or particle size is reduced. A decrease in airflow lowers the collection efficiency of the "spray catcher" elements which depend on particle impaction, but increases the time allowed for Brownian movement and, thus, increases the collection efficiency of the "high efficiency" elements. Higher airflows increase the inertial impaction of particulates on the "spray catcher" elements, while reducing the time allowed for Brownian movement on the "high efficiency" elements. These counter-balancing trends result in negligible collection efficiency shifts with changes in airflow. The same is also true for particle size or concentration shifts.[13]

4.2.2.2 Tray-Type Scrubbers. A tray-type scrubber is shown in Figure 4-4. It consists of a vertical tower containing one or more transversely mounted trays. Particulate laden gas enters the tower bottom and bubbles up through valves, perforations or other types of

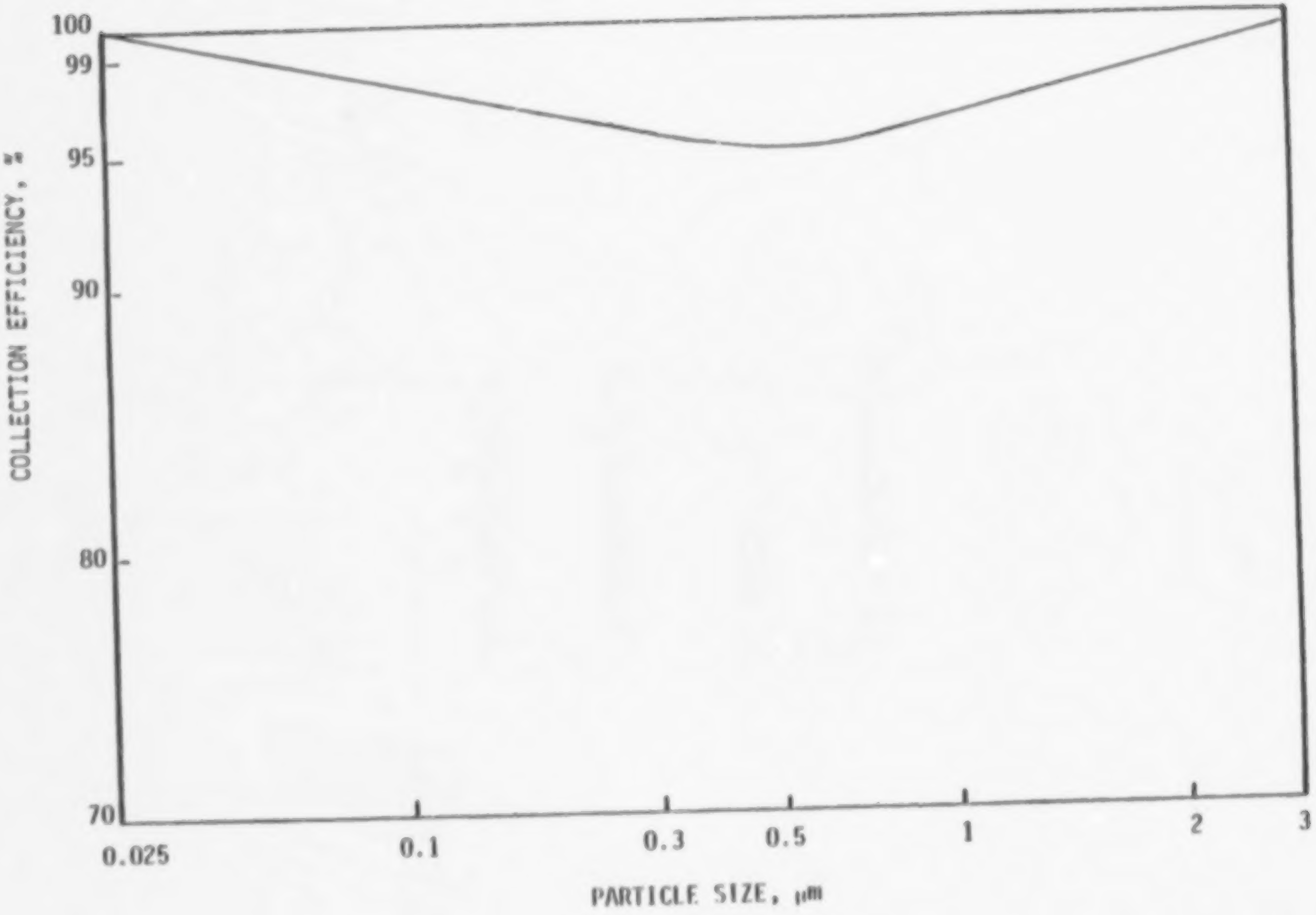

Figure 4-3. Collection efficiency vs. particle size for a wetted fibrous filter scrubber.[14]

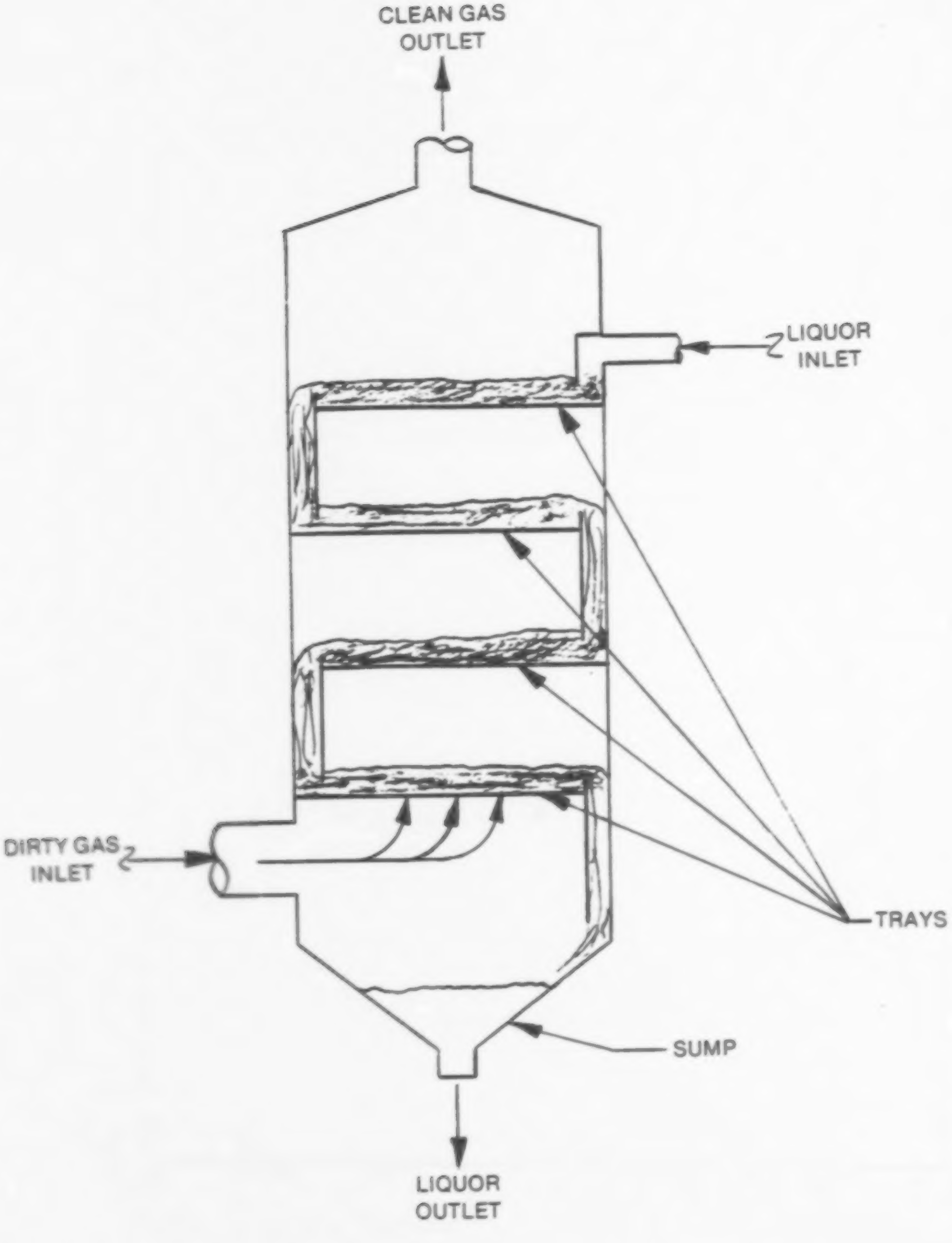
CLEAN GAS OUTLET
LIQUOR INLET
DIRTY GAS INLET
TRAYS
SUMP
LIQUOR OUTLET

Figure 4-4. Tray-type scrubber.

openings in each tray before exiting through the top of the tower. Usually scrubbing liquid is introduced at the top plate, where it flows across, over a retaining dam, and through a downcomer to reach the plate below.

Tray scrubbers do not exhibit the same removal efficiency for all particle sizes. They show a sharp efficiency drop at a specific particle size, which is determined primarily by the diameter of the plate perforations used. The cut diameter for a well designed tray scrubber is 2-3 microns. The liquid-to-air ratio for these devices ranges from 670 to 2010 liters/1000 m^3 (5 to 15 gal/1000 ft^3).[15]

The major factor affecting efficiency for a tray scrubber is pressure drop. Generally, higher pressure drops result in greater removal efficiencies. The number of trays, the size of the orifices in the tray, and the velocity of the gas stream through the scrubber control the pressure drop of the scrubber.

Manufacturers' performance curves show an increase in particulate removal with the addition of tower trays. Figure 4-5 illustrates this effect for a tray scrubber used in the ammonium nitrate industry for a variety of particle sizes. The efficiency of the vertical axis, termed standard efficiency, is for a standard 0.37 kPa (1.5 in W.G.) pressure drop per tray.

Increasing the pressure drop across each tray through the use of smaller orifices also increases removal efficiencies. Figure 4-6 illustrates this effect. For any given scrubber efficiency, the efficiency at a higher pressure drop can be read.

A higher liquid-to-gas ratio can usually increase particulate removal. However, an optimum liquid flow rate is usually maintained, which insures adequate liquor for particulate removal without blocking the airflow through the tray orifices.

4.2.2.3 Spray Tower Scrubbers. Spray tower scrubbers (Figure 4-7) typically consist of a vertical or horizontal tower containing banks of spray-nozzles. Either countercurrent, concurrent or crossflow spray configurations are used to spray droplets into the gas stream.

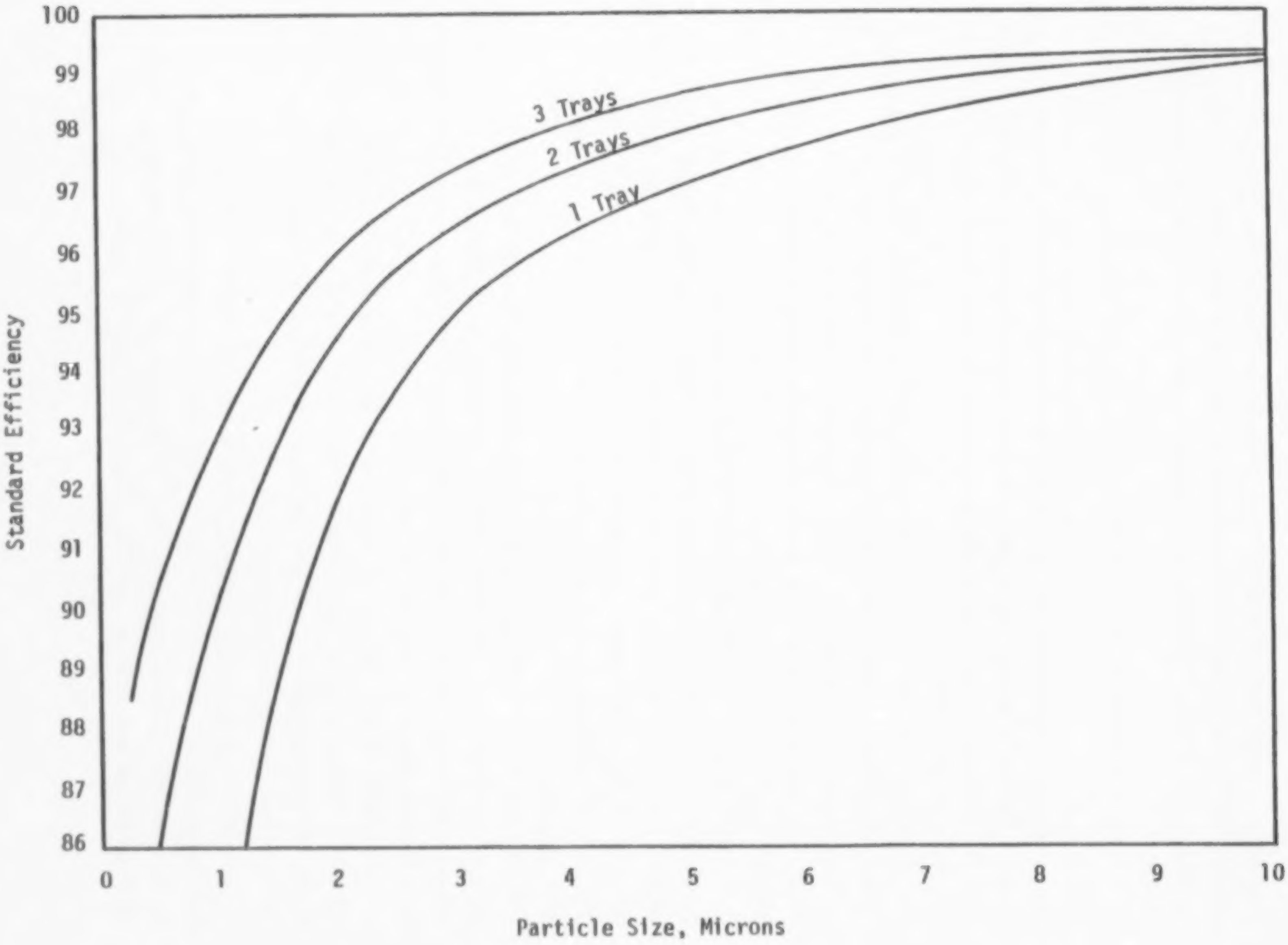

Figure 4-5. Standard fractional efficiency for tray-type scrubber.[16]

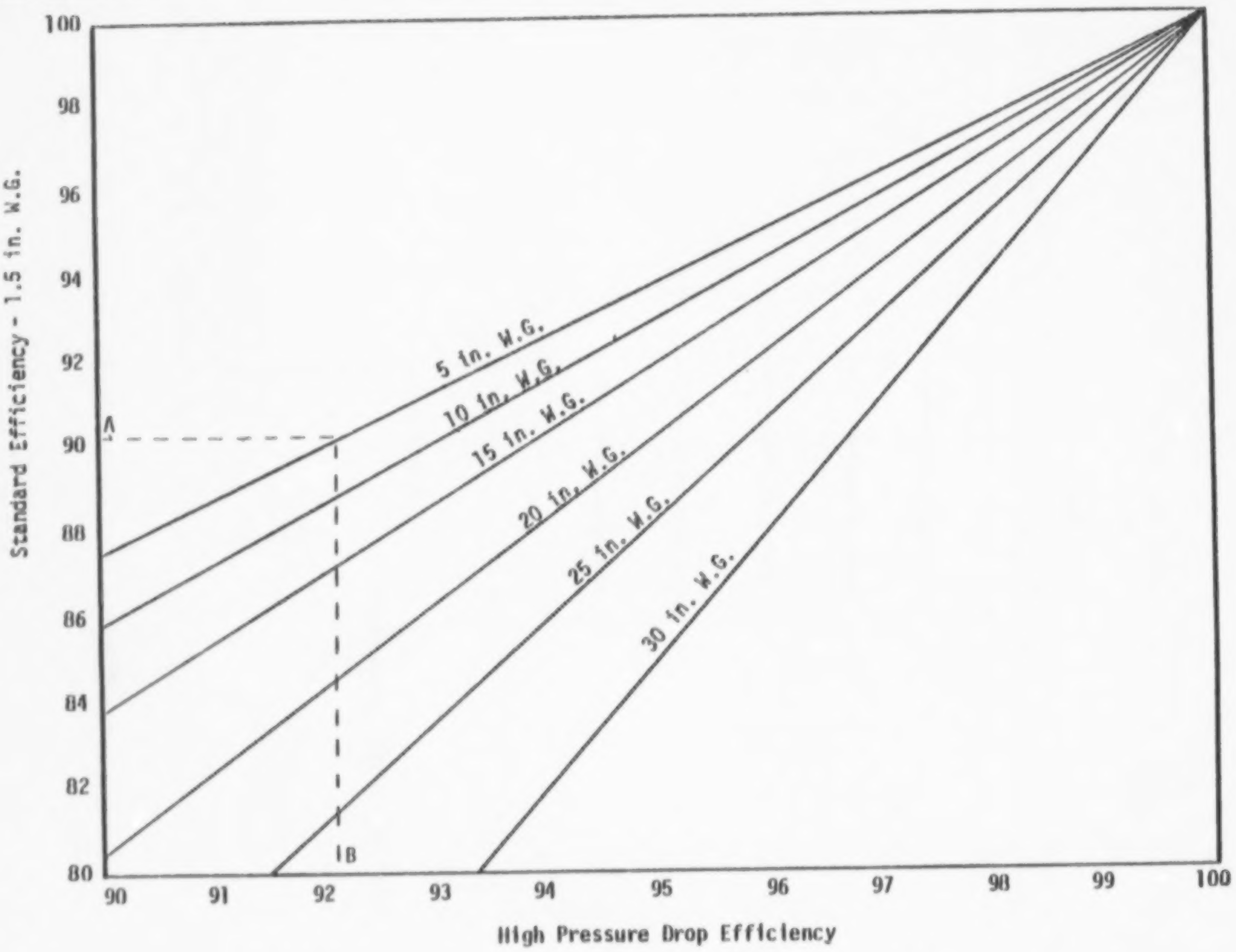

Figure 4-6. Effect of pressure drop on tray-type scrubber efficiency.[16]

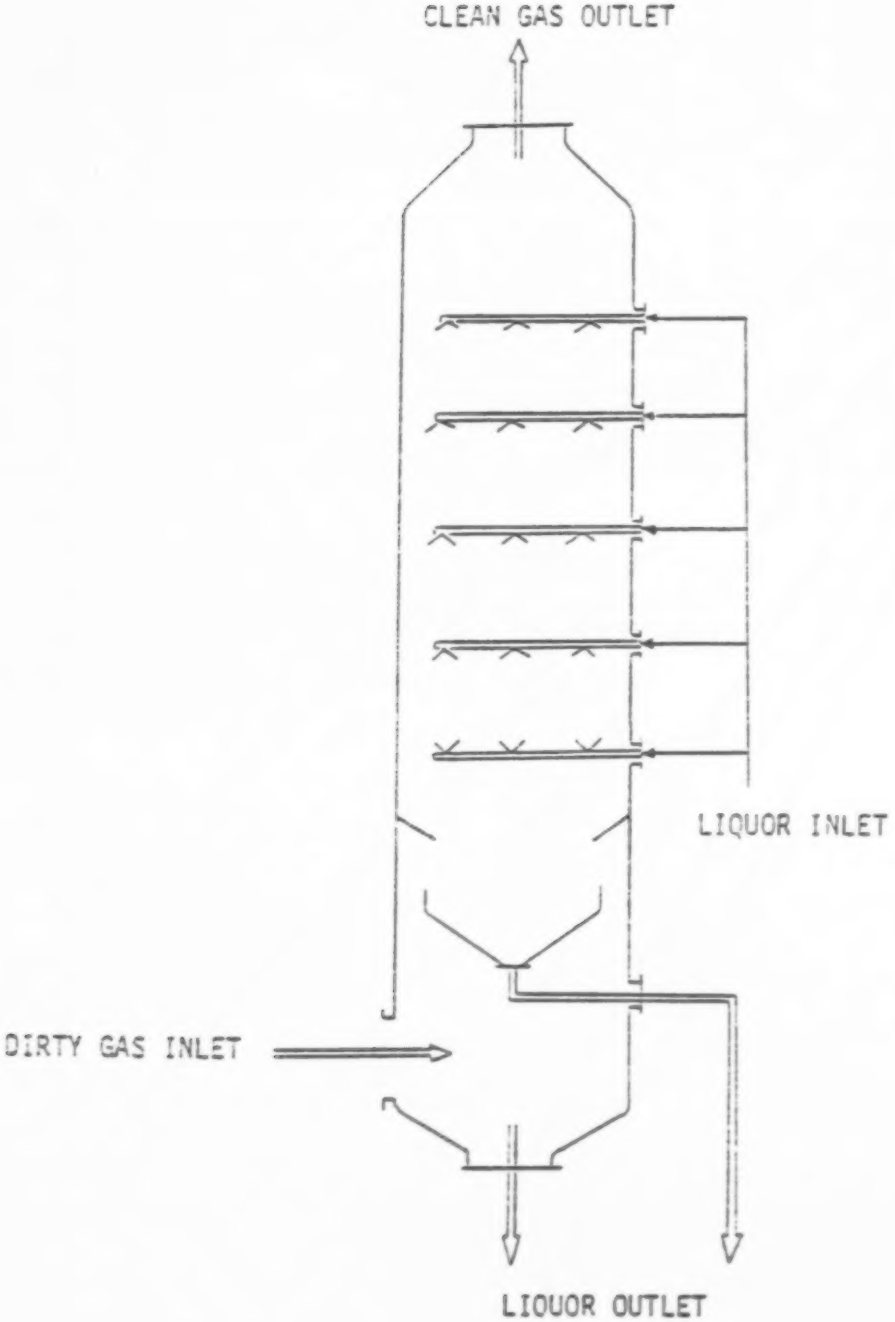
CLEAN GAS OUTLET
LIQUOR INLET
DIRTY GAS INLET
LIQUOR OUTLET

Figure 4-7. Spray tower scrubber.

Particles in the gas stream impinge on the liquid droplets, then are collected and removed from the bottom of the tower. Droplet properties are defined by the nozzle configuration, the type of liquid being atomized, and the pressure at the nozzle. Nozzle pressure is typically 790 to 1,480 kPa (100 to 200 psig) but can be as high as 2,860 kPa (400 psig) to remove submicron particles.[17,18]

Pressure drops across these scrubbers typically range from 0.12-0.50 kPa (0.5-2 in. W.G.), with gas velocities of 0.37 to 1.5 m/sec (1.5 to 5.0 ft/sec). The liquid-to-gas (L/G) ratio used in spray towers is generally 400 to 2674 liters/1000 m^3 (3 to 20 gal/1000 ft^3).[18,19] No performance curves are available for these scrubbers.

Factors reported to affect spray tower performance include droplet size, relative velocity between droplets and gas airflow, and the liquid-to-gas ratio. Large droplets provide less total surface area for impaction, thus decreasing the spray tower's particulate removal efficiency. On the other hand, small droplets increase particulate removal efficiency, since a larger total surface area is available for particle capture.

The relative velocity between droplets and gas airflow also determines removal efficiency. Large droplets have a higher relative velocity and improved chances of particle-droplet collisions because of the droplet's larger terminal settling velocity. Smaller droplets have a lower relative droplet-to-gas velocity, and, if too small, will be entrained in the rising gas stream. Therefore, an optimum droplet size can be found to enhance spray tower efficiency, depending on the particle size distribution and the flow rate of the gas stream. One optimum droplet size reported is in the range of 500-1,000 microns for particle sizes ranging from 2-10 microns.[19] Spray towers are capable of handling large gas airflows if the droplet size and pressure are adjusted accordingly.

The liquid-to-gas ratio also impacts tower performance. It must be high enough to insure effective particulate capture by the water droplets, but not so high that it hinders the flow of gas through the spray tower.

4.2.2.4 Venturi Scrubbers. A typical venturi scrubber is shown in Figure 4-8. Scrubbing liquid is injected into the gas stream upstream of the throat area. The moving gas stream first atomizes the liquid into droplets, then accelerates them through the throat. In the high turbulence zone associated with the venturi throat, particles collide with and are collected by the atomized liquid droplets. The particle laden liquid is then removed from the gas in a cyclonic separator.

Venturi scrubbers typically operate at pressure drops of 2.5 to 20 kPa (10 to 80 in. W.G.) and liquid to gas ratios of 400 to 1300 liters/1000 m^3 (3-10 gal/1000 ft^3). Scrubber capacity ranges from 1000 to 3400 m^3/min (35,000 to 120,000 ft^3/min). High gas velocities, usually 60-180 m/sec (200-600 ft/sec), are needed to keep the relative velocities between the gas and scrubber liquid droplets between 35 and 150 m/sec (120-500 ft/sec). The air velocity creates turbulence which mixes the particles and liquid droplets, thus increasing collection efficiency due to impingement and interception. Venturi scrubbers have cut diameters between 0.05 and 0.1 microns, depending on the pressure drop.[20,21,22]

Operating variables which affect venturi scrubber performance include pressure drop and the liquid-to-gas ratio. As shown in Figure 4-9, the collection efficiency for a specific particle size can be increased by increasing the pressure drop, and therefore the gas velocity. One type of venturi scrubber has a variable throat in order to maintain the pressure drop, and thus collection efficiency, at varying gas flows.[23] Like other wet scrubbers, the liquid-to-gas ratio for venturi scrubbers must be great enough to effectively sweep the gas flow, but not so great it causes flooding.

4.2.2.5 Entrainment Scrubbers. Entrainment scrubbers (also referred to as orifice type, self-induced spray or impingement scrubbers) utilize the velocity of the contaminated gas stream passing over the surface of a liquid to atomize part of the liquid.[24] These scrubbers feature a shell that guides the particle laden gas stream so that it impinges on and skims over the liquid surface before reaching a gas exit

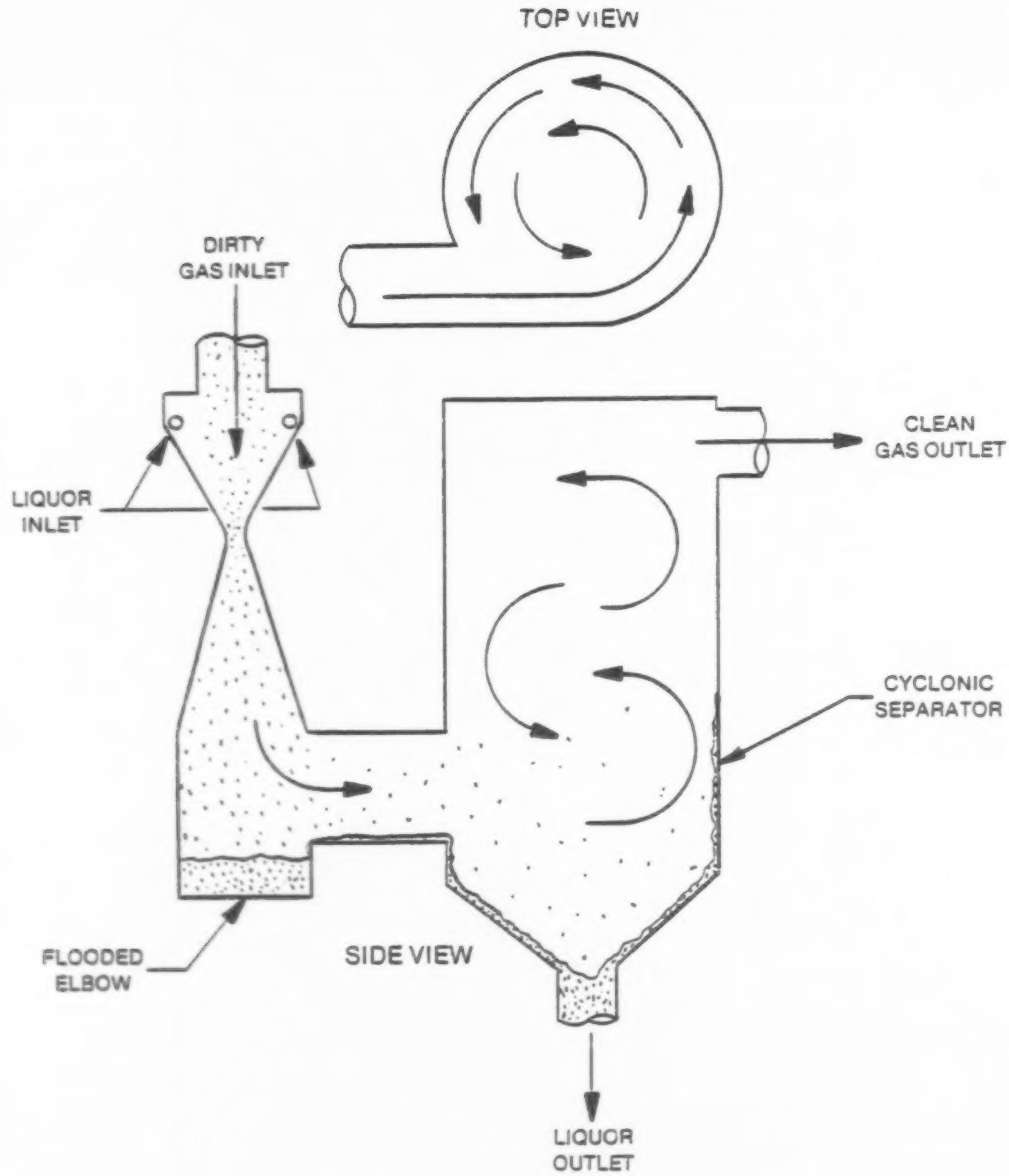
TOP VIEW
DIRTY GAS INLET
CLEAN GAS OUTLET
LIQUOR INLET
CYCLONIC SEPARATOR
FLOODED ELBOW
SIDE VIEW
LIQUOR OUTLET

Figure 4-8. Venturi and cyclonic scrubber.

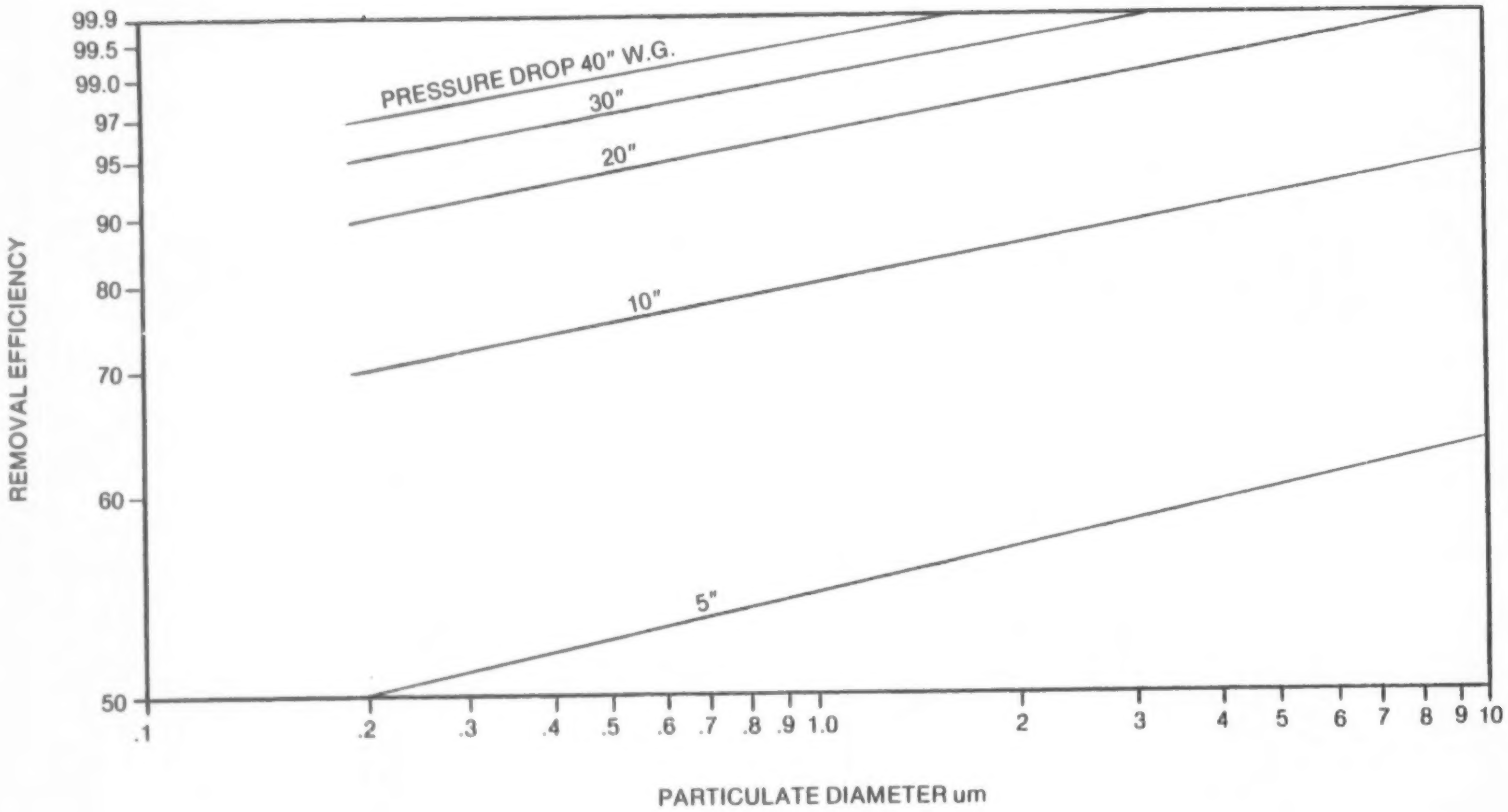

Figure 4-9. Collection efficiency vs. particle diameter for a venturi scrubber.[25]

duct (see Figure 4-10). The airflow atomizes some of the liquid into droplets; these act as a particle collecting and mass transfer surface. Particle collection results from both inertial impaction of the particles in the gas stream on the liquid surface and by impingement of the particles on the atomized droplets.[26] The particle laden droplets are removed from the gas stream by gravity and a set of spinner vanes. The spinner vanes force the droplets to contact the liquid surface and the sides of the device where they flow down to the sump.

The cut diameter for this type of entrainment scrubber ranges from 0.08 to 0.3 microns. The pressure drop ranges from 1-4 kPa (4-16 in W.G.).[27] Figure 4-11 presents the collection efficiency curves for this scrubber as a function of particle size and pressure drop.

The most important factor determining entrainment scrubber performance is pressure drop. Pressure drop may be adjusted by changing the liquid level in the sump.[28] Too low a pressure drop reduces impaction which decreases the scrubber collection efficiency. An excessive pressure drop reduces collection efficiency because of insufficient liquid to gas contact. Pressure drop is affected by gas airflow, but in entrainment scrubbers it is also affected by gas velocity. Entrainment scrubbers depend on the velocity of the inlet air to atomize the scrubber liquid. Therefore, even modest turndowns or reductions in air velocity will reduce the scrubber's collection efficiency. Entrainment scrubbers used in the ammonium nitrate industry handle the turndown problem by adjusting the gas nozzle, which directs the gas airflow into the liquid, to accomodate changes in the inlet air velocity so that collection efficiency will not be affected.[27]

4.2.2.6 Mechanically Aided Scrubbers. Mechanically aided scrubbers rely on fan blades for particle collection. Scrubbing liquid is typically introduced at the hub of the rotating fan blades. Particles in the gas stream are captured as they impinge on the blades, and on the liquid droplets atomized by the fan blades. Some liquid runs over the blades, washing them of collected particles. This liquid atomizes as it leaves

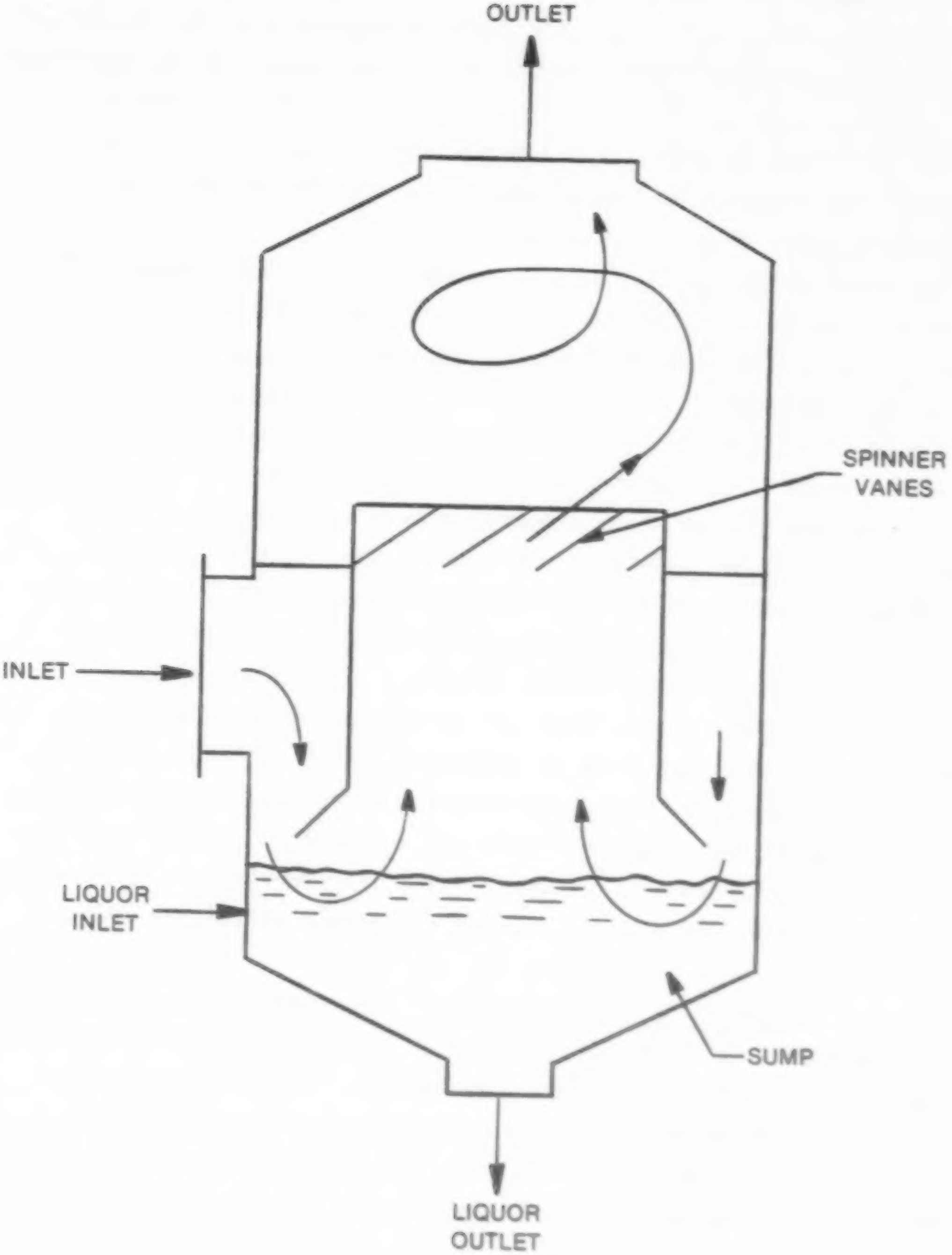
OUTLET
SPINNER VANES
INLET
LIQUOR INLET
SUMP
LIQUOR OUTLET

Figure 4-10. Typical entrainment scrubber.[29]

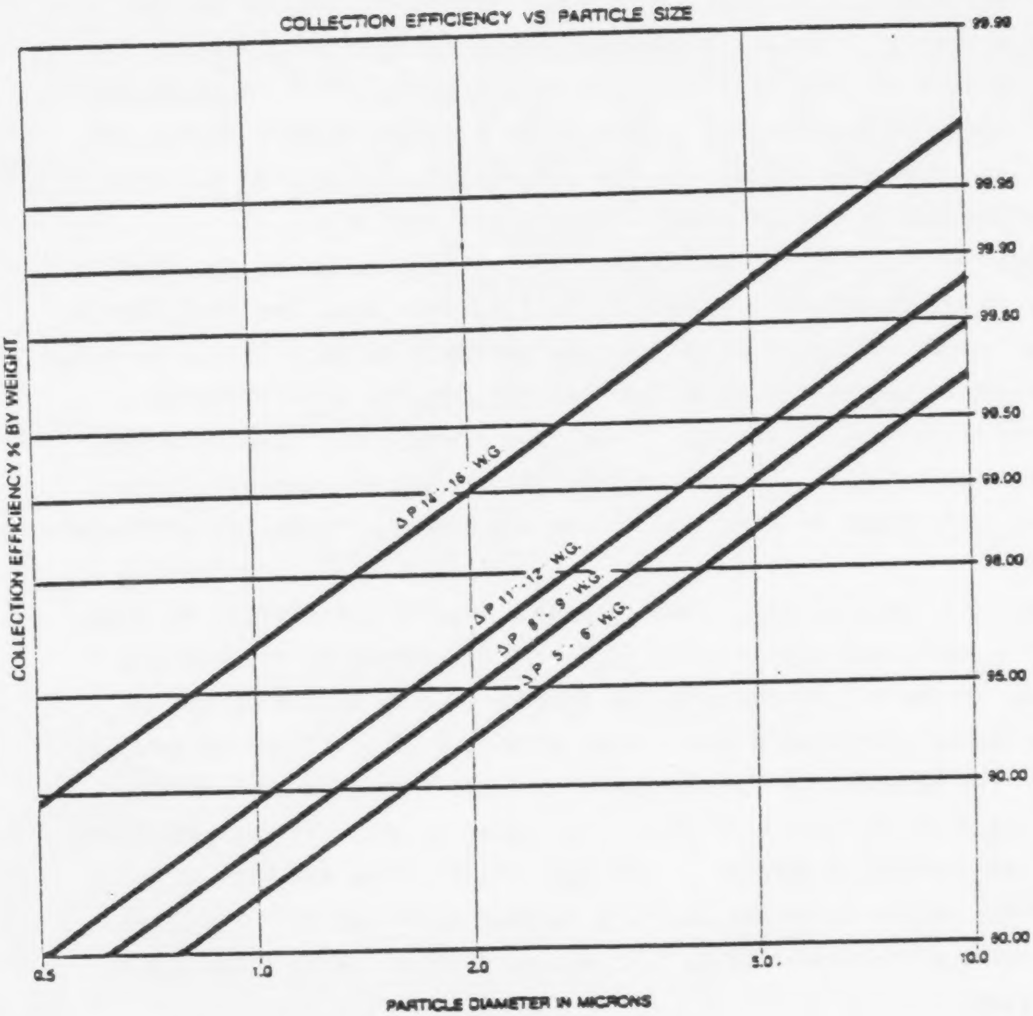

Figure 4-11. Collection efficiency of entrainment scrubbers as a function of particle size and pressure drop (courtesy of the Western Precipitation Division of Joy Manufacturing Company).[27]

the fan wheel and is recaptured by the fan housing, which drains into a sump. Figure 4-12 shows an example of a mechanical centrifugal scrubber.

Pressure drops for these scrubbers are low (0.25-1.5 kPa (1-6 in. W.G.)) and have little effect on removal efficiency, because the fan blades primarily atomize the scrubber liquor instead of increasing the gas flow rate and also serve as a collection device.[30,31] Mechanical centrifugal scrubbers generally have a cut diameter below 1 micron and liquid-to-gas ratios of 2680 to 5360 liters/1000 m^3 (20 - 30 gal/1000 ft^3).[31] No performance curves for these scrubbers are available.

One factor affecting performance of this device is the amount of liquid on the fan blade. If too little liquid is used, the particles in the gas stream will pass on through the device. Too much liquid increases the amount of wastewater to be handled, but does not significantly increase performance. Changes in gas flow do not significantly affect scrubber performance. However, higher fan velocities generally cause greater impingement of particles on the fan blades, increasing particulate removal.[32]

4.2.2.7 Wet Cyclones. Wet cyclones, usually cylindrical in shape, impart a rotational motion to the incoming gas stream by tangentially introducing the gas stream into the scrubber, or by directing the gas stream against stationary swirl vanes (Figure 4-13). Liquid is sprayed through the rotating gas stream either outward from a central manifold, or inward from the collector wall. Particles in the swirling gas stream impact on the liquid droplets. The centrifugal force and high velocity of the gas stream carry the particle laden droplet out to the cyclone wall, where a continuous water film washes it down the wall and out of the system.

Wet cyclones generally operate at 0.50-1.5 kPa pressure drops (2-6 in. W.G.).[8] This pressure loss is directly proportional to the gas stream flow rate. Wet cyclone scrubbers are designed for cut diameters between 2 and 3 microns, with liquid-to-gas ratios of 268 to 1340 liters/1000 m^3 (2-10 gal/1000 ft^3).[33] No efficiency curves for these scrubbers are available.

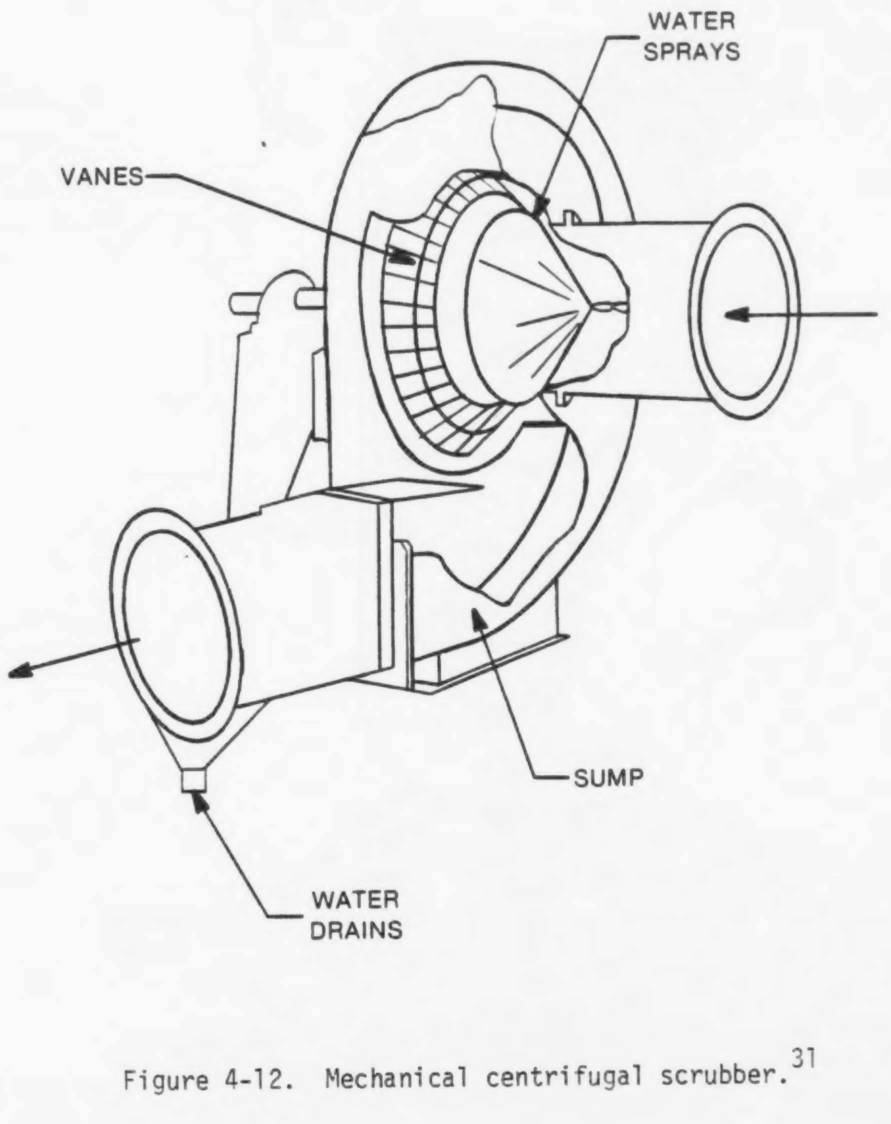
WATER SPRAYS
VANES
SUMP
WATER DRAINS

Figure 4-12. Mechanical centrifugal scrubber.[31]

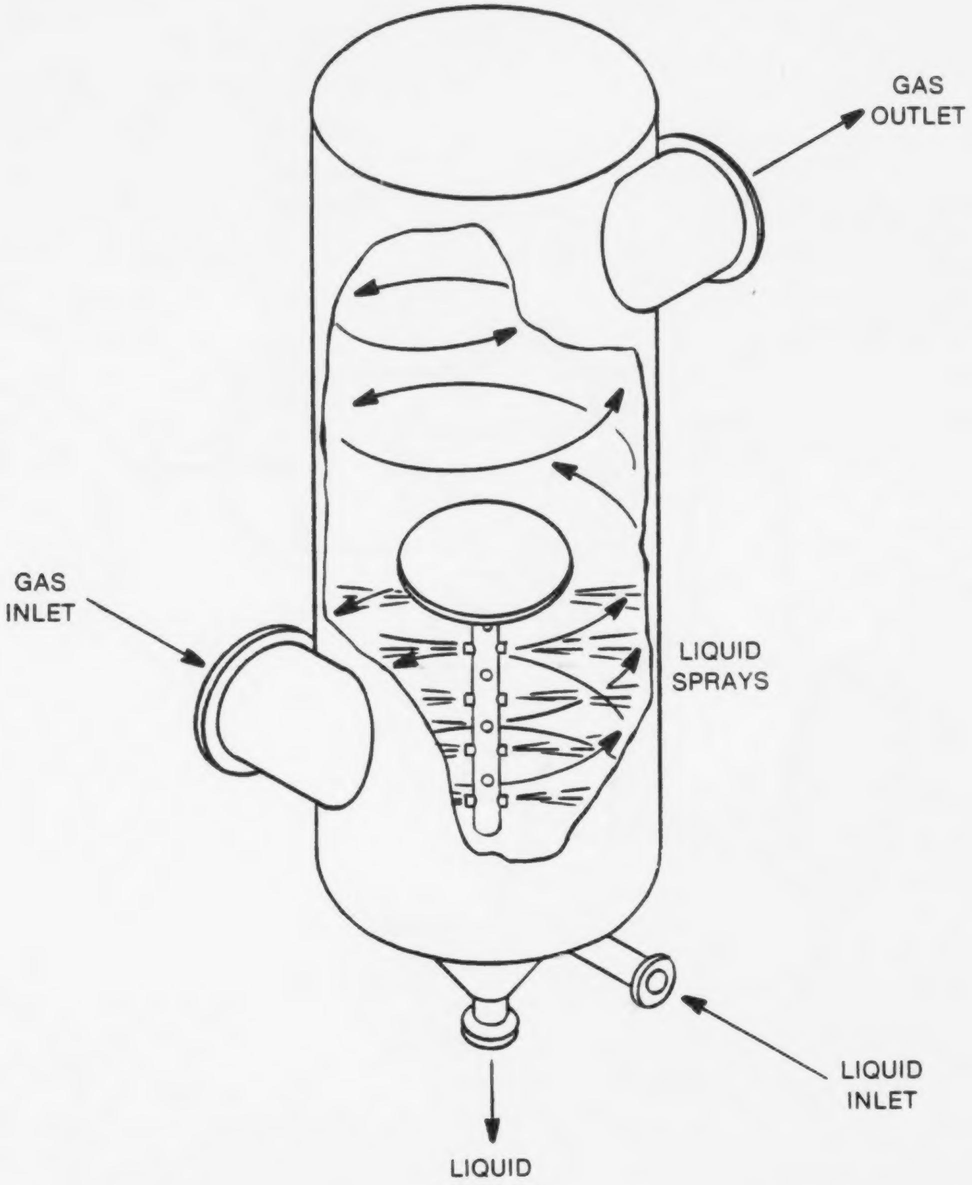
GAS
OUTLET
GAS
INLET
LIQUID
SPRAYS
LIQUID
INLET
LIQUID
OUTLET

Figure 4-13. Wet cyclone scrubber.

Since it directly influences pressure drop the gas flow rate is the most important factor affecting the performance of a wet cyclone. If the gas flow rate is lowered, scrubber efficiency will be reduced.

4.2.3 Fabric Filters

Fabric filters (baghouses) are high efficiency collection devices used quite extensively in the ammonium nitrate industry for control in bagging and coating operations. An average removal efficiency for a fabric filter is 99 percent.[34] Figure 4-14 depicts a typical fabric filter system. In the type of design shown, the airstream enters the baghouse and is pulled up into fabric sleeves located throughout the baghouse. The air pulled through these fabric sleeves is exhausted to the atmosphere, while dust remains trapped in the weave of the fabric, forming a layer of dust on the bag. The pressure drop through the bag increases as this dust layer builds up. The dust is eventually removed from the bag by one of several bag cleaning methods.

An important operating principle for fabric filters is that effective filtering of the dusty airstream is accomplished, not only by the fabric, but also by the dust layer which forms on the fabric. This dust layer bridges the gaps between adjacent fibers and increases the chances of impaction and interception of small particles. For this reason, too frequent cleaning can actually decrease efficiency by not allowing a dust layer to accumulate between cleaning cycles.

Materials available for bag construction are numerous. They include cotton, Teflon^R, coated glass, orlon, nylon, dacron and wool. The type of material selected depends upon many factors, including temperature, frequency of cleaning, ease of removing particles, resistance to chemical attack, and abrasion characteristics of the collected particles.

Factors affecting baghouse performance include air-to-cloth ratio, type of fabric used, method and interval of cleaning, pressure drop, and the properties of the exhaust being cleaned. Air-to-cloth ratio is dimensionally equivalent to a velocity; and it indicates the average face velocity of the gas stream through the effective area of the fabric.

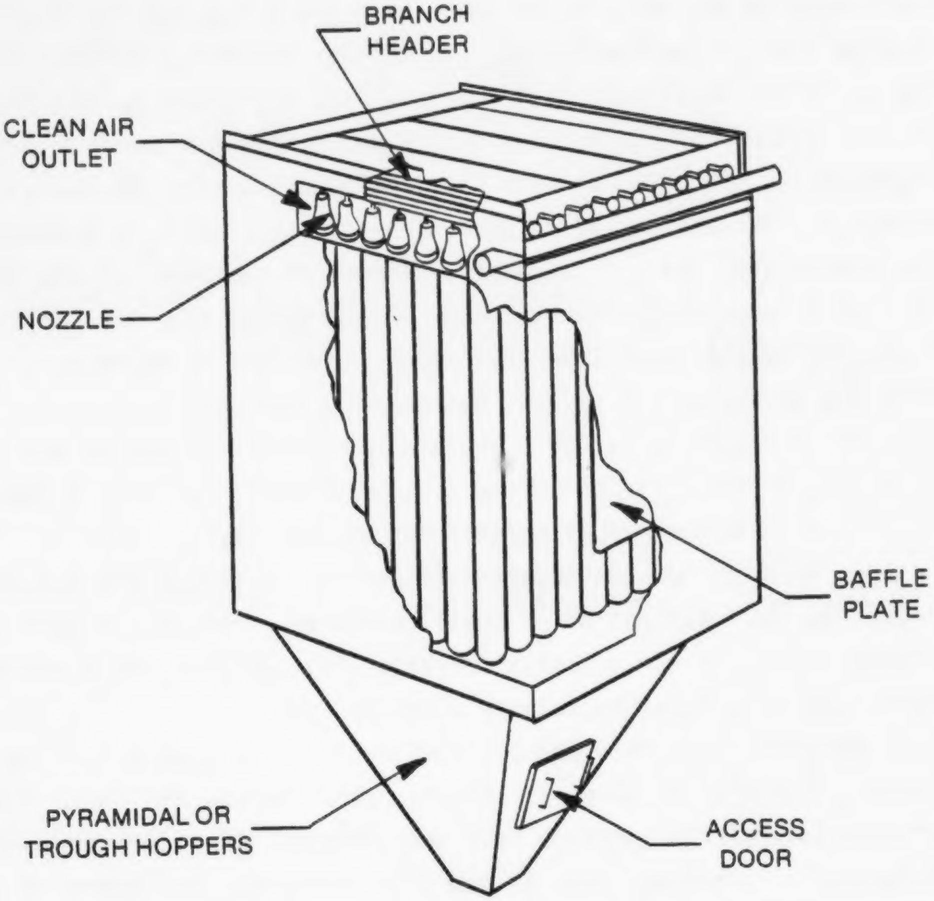
BRANCH HEADER
CLEAN AIR OUTLET
NOZZLE
BAFFLE PLATE
PYRAMIDAL OR TROUGH HOPPERS
ACCESS DOOR

Figure 4-14. Fabric filter.[35]

An excessive air-to-cloth ratio results in excessive pressure loss, reduced collection efficiency, rapid bag blinding, and increased wear on the fabric. Too low an air-to-cloth ratio reduces collection efficiency, since the filtering dust layer may not be allowed to accumulate between cleaning cycles.

Pressure drops in baghouses depend on a variety of factors, including air-to-cloth ratio, fabric type and cleaning cycle. Pressure drops typically increase between cleaning cycles as the dust layer increases. Pressure drops of from 0.5-2 kPa (2 - 8 in. W.G.) are common for many applications.[36]

4.2.4 Modifications in the Process Parameters

In addition to the control devices mentioned above, emissions from high density prill towers can be reduced by varying process parameters. One industry study was conducted in 1973 on a high density prill tower to determine the effect on the emission rate of raising the melt pH, reducing the melt spray temperature, reducing the tower air flow and adding magnesium oxide to the spray melt.[37]

As the pH increased from 5.5 to 7.0, emission rates reduced by approximately one-third and prill formation became larger and irregular in size and shape. The study concluded that while emissions decreased at increased melt pH's, plants could not operate at pH's of 7.0 or above without equipment modification or changes in prill quality standards.

When the spray temperature was reduced from 455 K (360°F) to 447 K (345°F), emissions were reduced by as much as 20 percent. This reduction in emissions is believed to be due to the reduction of fuming.

To study the effect of lower tower airflows on emissions, the airflow was reduced from 3823 Nm^3/min (135,000 scfm) to 2265 Nm^3/min (80,000 scfm). The data showed that while emission concentrations increased due to the reduced airflow, emission rates remained normal. No emissions reduction was observed.

MgO was added continuously to the head tank of a high density prill tower to maintain concentrations of 0.10 to 0.14 weight percent of free

MgO. The emission rates measured from all samples were considered normal and showed no change.

These emissions tests were conducted by using a test method other than the EPA method ("modified" Method 5 or AN-MOD 5) and should only be used as an indication of possible performance. Regardless of the potential emissions reductions possible with the above modifications, the study concluded that control equipment would still be necessary to reduce emissions on high density prill tower operations to meet state air emission regulations.

4.3 EMISSIONS TEST DATA

The following section presents the available test data for solids formation and solids finishing processes in the ammonium nitrate industry. The information is divided into two categories: data supplied by industry and state air pollution agencies (hereafter referred to as industry data), and data collected by EPA during source testing conducted for this study. In general, available industry data are limited and were obtained by widely varying sampling and analytical techniques. Because of the differences in sampling and analytical procedures, direct comparisons between industry and EPA data cannot be made.

4.3.1 High Density Prill Towers

As mentioned in previous sections, the most commonly used control system for high density prill towers is a collection hood and a wetted fibrous filter scrubber. Several of these systems have been tested by industry.

Table 4-2 summarizes available mass emission test results for high density prill towers, in addition to low density prill towers and granulators. For high density prill towers, uncontrolled particulate emissions range from 0.81 to 2.74 g/kg (1.63 to 5.48 lb/ton) and controlled emissions range from 0.03 to 0.85 g/kg (0.07 to 1.69 lb/ton). Some treatment systems only treat a portion of the total tower emissions; reported controlled emissions for these systems are the sum of the treated air emissions and the bypass emissions.

TABLE 4-2. HIGH DENSITY AND LOW DENSITY PRILL TOWER AND GRANULATOR EMISSIONS[38]

		Uncontrolled Emissions g/kg (lb/ton)			Controlled Emissions g/kg (lb/ton)			
Plant	Type of Plant	Ammonia	Ammonium Nitrate	Control Device	Ammonia	Ammonium Nitrate	Percent of Airflow to Device	Percent of Emissions to Control Device
A[a]	High Density Prilling	28.80 (57.60)	1.60 (3.20)	Two Tray Scrubber	4.70 (9.40)	0.85 (1.69)	100	100
G[b]	High Density Prilling	NA	2.74 (5.48)	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.40 (0.81)	c	88
H[b]	High Density Prilling	NA	1.16 (2.33)	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.51 (1.02)	33	NA
I[b]	High Density Prilling	NA	1.28 (2.55)	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.16 (0.32)	21	84
P[b]	High Density Prilling	NA	1.93 (3.86)	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.24 (0.48)	25	89
Z[b]	High Density Prilling	NA	NA	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.03 (0.07)	NA	NA
O[b]	High Density Prilling	NA	0.82 (1.63)	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.29 (0.57)	25	67
J[b]	Low Density Prilling	NA	0.22 (0.45)	Wet Impingement Scrubber	NA	0.11 (0.21)	DNA	100
Z[b]	Low Density Prilling	NA	NA	Collection Hood Wetted Fibrous Filter Scrubber	NA	0.06 (0.13)	NA	NA
Z[a]	Low Density Prilling	0.13 (0.26)	0.39 (0.78)	Collection Hood Wetted Fibrous Filter Scrubber	0.07 (0.14)	0.25 (0.49)	17	42
B[a]	Drum Granulator	30 (60)	147 (295)	Entrainment Scrubbers	0.09 (0.18)	0.22 (0.43)	DNA	100
E[b]	Drum Granulator	NA	NA	Entrainment Scrubber	NA	0.61 (1.23)	DNA	100
D[a]	Pan Granulator	0.07 (1.15)	1.34 (2.68)	Variable Throat Venturi Scrubber	d	0.02[e] (0.04)	DNA	100

DNA = Does Not Apply
NA = Not Available

[a] EPA Test Data.

[b] Industry Data (not necessarily comparable with EPA data).

[c] Considered confidential by this plant but within range of other reported values.

[d] Controlled emissions are from the evaporator and pan granulator. Controlled ammonia emissions are unavailable due to the high ammonia emissions from the evaporator.

[e] Controlled emissions are from the evaporator and pan granulator. The pan granulator AN particulate emissions constitute 98 percent by weight of the scrubber inlet emission.

EPA tested a high density prill tower controlled by a two tray scrubber with a pressure drop of 2.7 kPa (10.7 in. W.G.) (see Appendix A).[2] The emission rate was reduced from 1.60 g/kg (3.20 lb/ton) to 0.85 g/kg (1.69 lb/ton) of product. The AN particulate concentration was 0.07 g/dNm^3 (0.03 gr/dscf) at the inlet to the scrubber and 0.036 g/dNm^3 (0.016 gr/dscf) at the outlet.[39] Average visible emissions from the scrubber ranged from 10 to 20 percent opacity.[40] No particle size data was available for this test.

4.3.2 Low Density Prill Towers

The most commonly used control technique applied to low density prill towers is the same as that for high density prill towers: a collection hood and a wetted fibrous filter scrubber. As shown in Table 4-2, uncontrolled particulate emissions range from 0.21 g/kg (0.42 lb/ton) to 0.69 g/kg (1.38 lb/ton), while controlled emissions range from 0.06 to 0.25 g/kg (0.13 to 0.49 lb/ton).

EPA's testing of a collection hood/wetted fibrous filter system, with a pressure drop of 3.5 kPa (14 in. W.G.), measured uncontrolled emissions of 0.39 g/kg (0.78 lb/ton).[41,42] Controlled emissions, the sum of emissions from the wetted fibrous filter scrubber and the bypass, were 0.24 g/kg (0.48 lb/ton). Particle size data for the bypass and the inlet to the wetted fibrous filter scrubber are presented in Figure 4-15. EPA also measured particulate concentrations. For the bypass, the average concentration was 0.013 g/dNm^3 (0.0056 gr/dscf); the fibrous filter inlet and outlet concentrations were 0.048 g/dNm^3 (0.021 gr/dscf) and 0.005 g/dNm^3 (0.002 gr/dscf), respectively.[42] Opacity reading from the bypass ranged from 0-8 percent and was 0 at the scrubber outlet.[43]

4.3.3 Rotary Drum Granulators

At present, all rotary drum granulators are controlled by entrainment scrubbers. The available emission test data from industry for two drum granulators are shown in Table 4-2. One of the plants measured only controlled emissions and reported these to be 0.61 g/kg (1.23 lb/ton). The other plant uses an entrainment scrubber with a 2.7 kPa (10.9 in. W.G.)

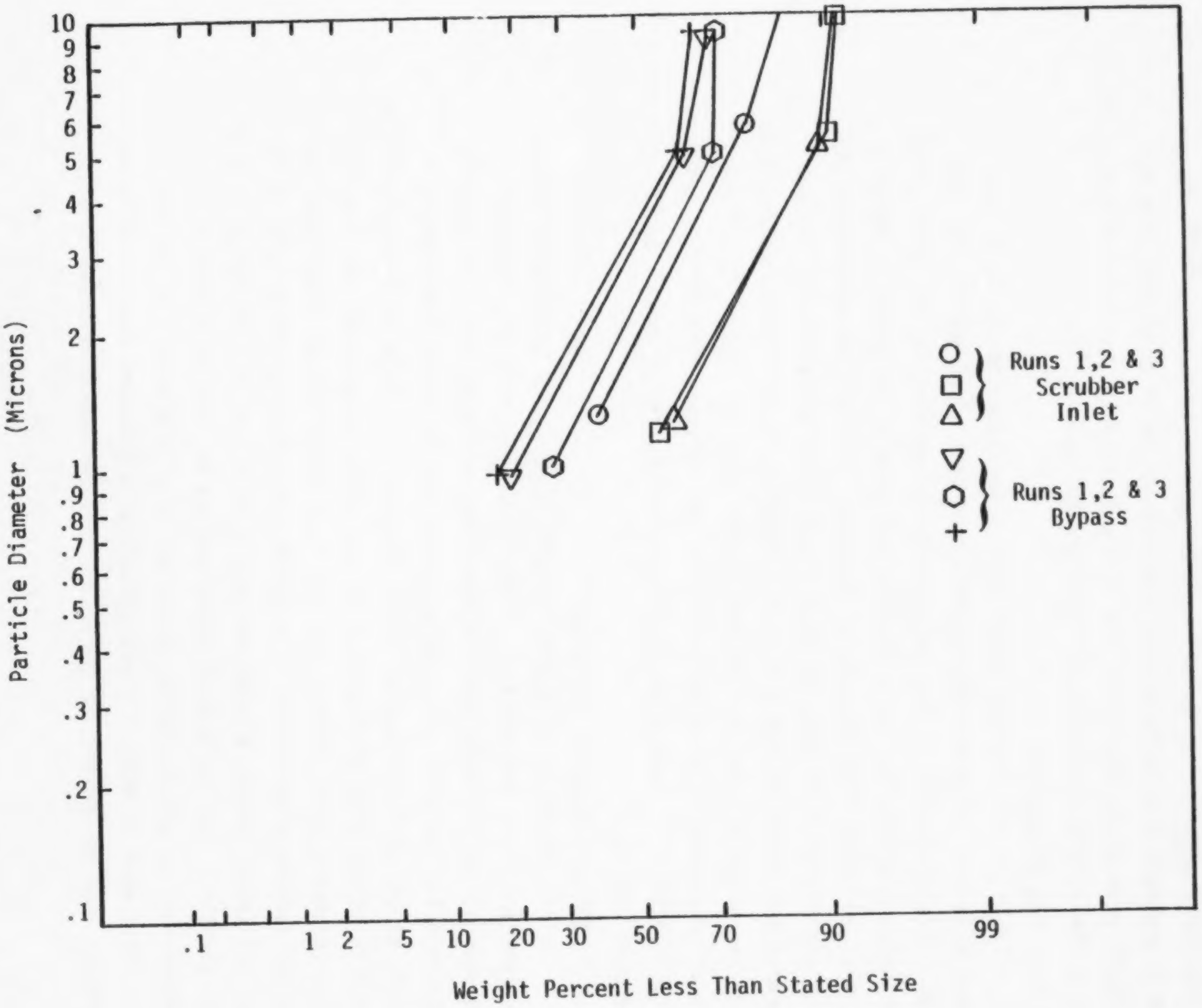

Figure 4-15. Particle size distribution from the bypass and the scrubber inlet at a low density prill tower.44

pressure drop and results of EPA testing show that emissions were reduced from 147.2 g/kg (294.6 lb/ton) to 0.22 g/kg (0.43 lb/ton).[45,46] Figure 4-16 presents the particle size characteristics of emissions from the rotary drum granulator. The EPA test also reports that visible emissions from the scrubber ranged from 10-20 percent opacity.[47]

4.3.4 Pan Granulators

There is only one pan granulator in operation in the U. S. and it uses a venturi scrubber with a pressure drop of 6.75 kPa (27 in. W.G.) for emission control.[7] EPA tests measured uncontrolled AN particulate emission from the pan granulator at 1.34 g/kg (2.68 lb/ton). Measured outlet emissions from the venturi scrubber include both evaporator and pan granulator emissions, so actual controlled emissions for the pan granulator alone are not available. However, controlled emissions from the pan granulator can be estimated based upon its proportion of the inlet emissions. The estimated controlled emission rate is 0.02 g/kg (0.04 lb/ton).[48] Controlled visible emissions ranged from 5 to 15 percent opacity.[49]

4.3.5 Solids Finishing Processes

Solids finishing equipment includes rotary drum predryers, dryers, coolers and fluid bed coolers. These units are discussed together because of their similarities in operation and emissions. As shown in Figure 4-17, particle sizes for uncontrolled emissions from various types of solids finishing equipment are similar. Each of these facilities have emissions with 99.7 percent of the particles greater than one micron.

Presently, wet cyclones are the most common wet scrubber used for solids finishing equipment. The designs for these scrubbers are varied, but all report pressure drops between 0.5-1.5 kPa (2-6 in. W.G.). Other wet scrubbers used to control emissions are mechanical scrubbers, entrainment scrubbers, spray towers and tray scrubbers. Of the wet scrubbers used to control these emissions, all report removal efficiencies greater than 95 percent for particles greater than 5 microns in size.

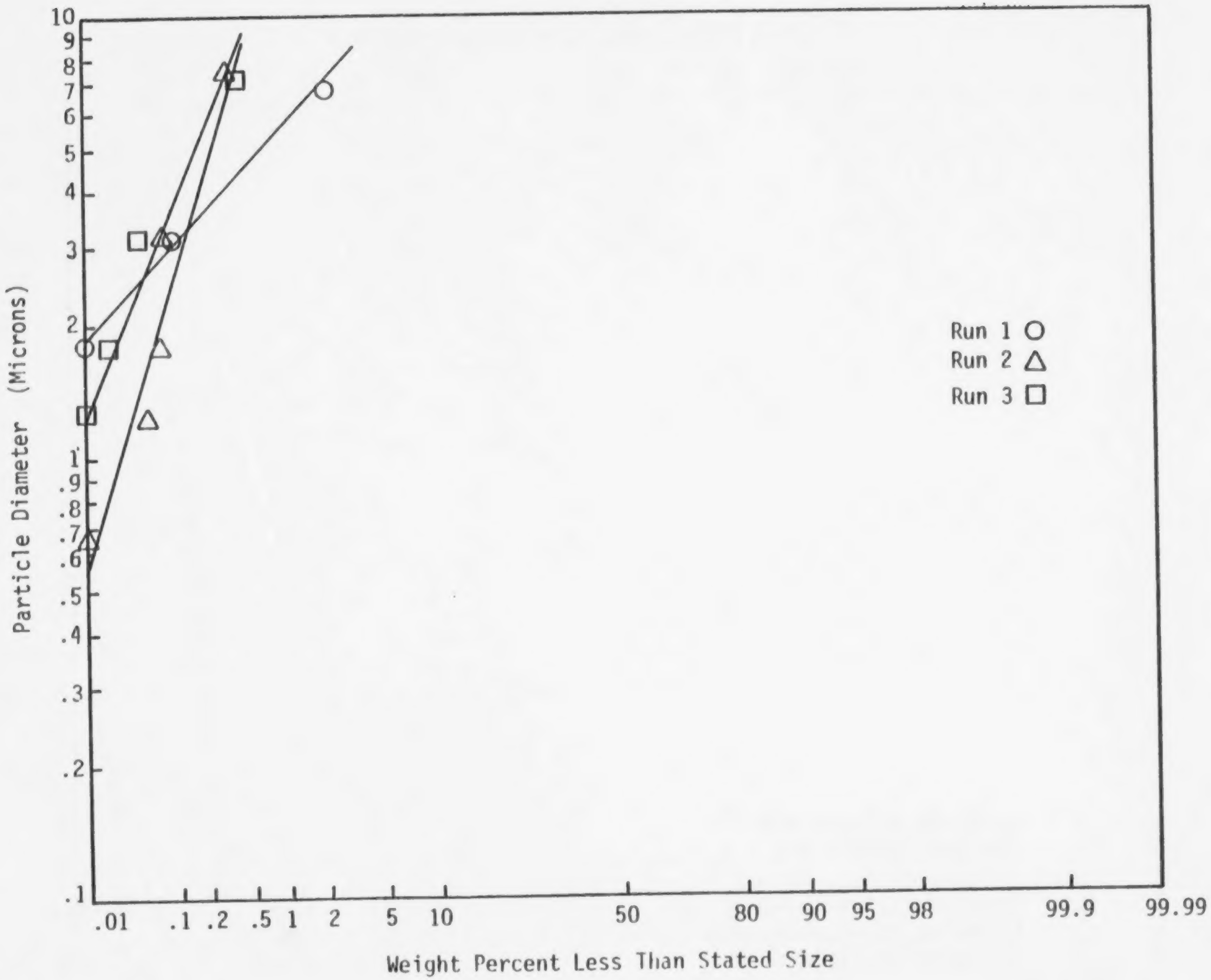

Figure 4-16. Particle size distribution of uncontrolled emissions from a rotary drum granulator.[50]

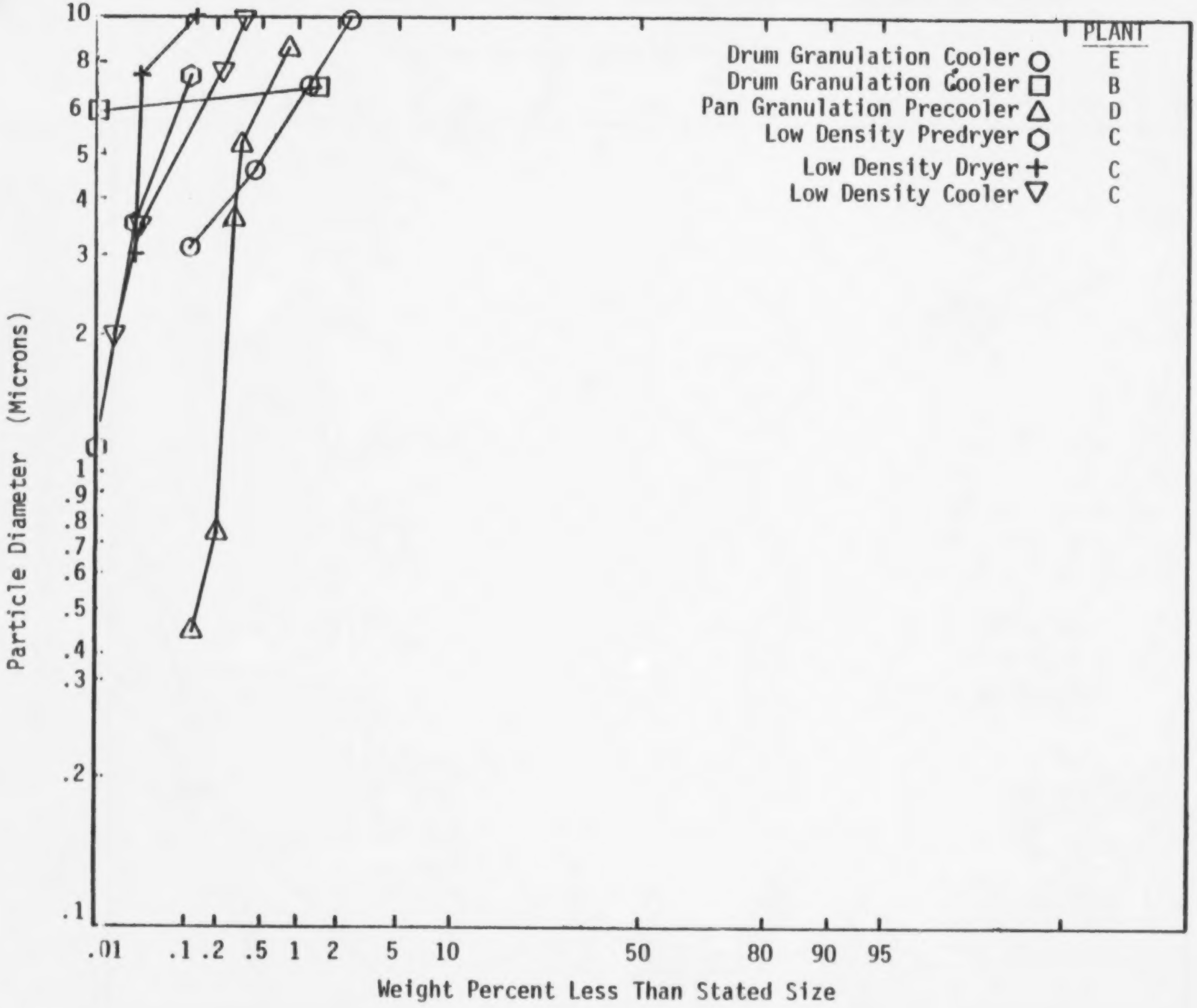

Figure 4-17. Average particle size distribution from solids finishing processes.

EPA and industry emission data on these facilities are presented in Table 4-3. Uncontrolled emission factors from both industry and EPA tests range from 0.15 to 93.7 g/kg (0.3 to 187.4 lb/ton) of ammonium nitrate. Controlled emission factors range from 0.003 to 0.65 g/kg (0.007 to 1.3 lb/ton) of ammonium nitrate. EPA tested the solids finishing equipment at high density, low density, drum granulation and pan granulation plants. Uncontrolled emissions for these EPA tests ranged from 0.83 to 93.7 g/kg (1.66 to 187.4 lb/ton) and the controlled emissions ranged from 0.03 to 0.47 g/kg (0.07 to 0.94 lb/ton). Appendix A contains details of the EPA testing of these facilities.

4.4 EVALUATION OF CONTROL DEVICE PERFORMANCE

This section presents an evaluation of the EPA emission data obtained during this study. This evaluation includes: (1) a general examination of the data to determine its relative accuracy and representativeness, and (2) a discussion of the control devices used and their removal capabilities. More details of the tests are presented in Appendix A.

4.4.1 High Density Prill Tower

EPA has tested only one high density prill plant (Plant A) in the ammonium nitrate industry. As can be seen from Tables 3-3 and 3-6, this plant's prill tower design and process parameters (like spray melt temperature, airflow rate and prill temperatures) are similar to other high density prill plants in the industry. Therefore, the process operation for Plant A can be considered representative of other plants in the industry. The tower at this plant has a 2.7 kPa (10.7 in. W.G.) pressure drop two-tray scrubber that controls total tower airflow.[2] This is the only high density plant in the industry which uses this type of scrubber. The scrubber usually controls evaporator and prill tower emissions, but during testing only prill tower emissions were controlled.

Uncontrolled emissions were reduced from 1.6 g/kg (3.2 lb/ton) to 0.85 g/kg (1.69 lb/ton) by the two-tray scrubber, a 47 percent removal efficiency.[39] During the test the plant was operating normally. Nonisokinetic conditions occurred for two runs; however, the results were used in the

TABLE 4-3. SOLIDS FINISHING PROCESS EMISSIONS[a],51

Plant	Facility	Control Device	Pressure Drop kPa(in. W.G.)	Uncontrolled Emissions g/kg (lb/ton) Ammonia	Uncontrolled Emissions g/kg (lb/ton) Ammonium Nitrate	Controlled Emissions g/kg (lb/ton) Ammonia	Controlled Emissions g/kg (lb/ton) Ammonium Nitrate	Percent Opacity
	Predryers Low Density							
L_1^b	Rotary Drum Predryer[g]	Spray Tower	0.5-1.25 (2-5)	-	3.2 (6.4)	-	0.13 (0.26)	-
L_2^b	Rotary Drum Predryer[g]	Wet Cyclone	0.75-1.5 (3-6)	-	4.1 (8.2)	-	0.12 (0.25)	-
Z^b	Rotary Drum Predryer	Tray Scrubber	-	-	-	-	0.03 (0.06)	-
Z	Rotary Drum Predryer	Tray Scrubber	-	0.29 (0.58)	37.3 (74.6)	-	0.18 (0.36)[e]	0.2[f]
	Dryers Low Density							
L_1^b	Rotary Drum Dryers	Spray Tower	0.5-1.25 (2-5)	-	22.8 (45.7)	-	0.18 (0.37)	-
L_2^b	Rotary Drum Dryer	Wet Cyclone	0.75-1.5 (3-6)	-	7.8 (15.6)	-	0.1 (0.2)	-
Z^b	Rotary Drum Dryer	Tray Scrubber	-	-	-	-	0.03 (0.06)	-
Z	Rotary Drum Dryer	Tray Scrubber	-	1.3 (2.6)	93.7 (187.4)	-	0.47 (0.94)[e]	0.2[f]
	Coolers High Density							
A	Rotary Drum Cooler	Spray Chamber	1.0 (4.0)	0.03 (0.05)	0.83 (1.66)	0.01 (0.02)	0.075 (0.15)	0
G^b	Rotary Drum Cooler	Wetted Mesh Pad	0.5-0.75 (2-3)	-	0.15 (0.3)	-	0.003 (0.007)	-
Z^b	Fluid Bed Cooler	Wet Cyclone	-	-	-	-	0.31 (0.61)[d]	-
	Low Density							
L_1^b	Rotary Drum Cooler	Spray Tower	0.5-1.25 (2-5)	-	19.2 (38.4)	-	0.16 (0.32)	-
L_2^b	Rotary Drum Cooler	Wet Cyclone	0.75-1.5 (3-6	-	35.2 (70.5)	-	0.65 (1.3)	-
Z^b	Fluid Bed Cooler	Wet Cyclone	-	-	-	-	0.07 (0.14)[d]	-
Z	Fluid Bed Cooler	Wet Cyclone	-	0.29 (0.58)	37.8 (75.7)	-	-	0
	Drum Granulation							
E	Rotary Drum Cooler	Entrainment Scrubber	3.3 (13.1)	1.18 (2.35)	8.6 (17.3)	0.02(0.03)	0.03 (0.07).	-
	Pan Granulation							
D	Rotary Drum Precooler[c]	Wet Cyclone	1.4 (5.6)	0	18.0 (36.0)	0	0.12 (0.23)	0-10

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[a] EPA data unless otherwise noted.

[b] Industry data.

[c] Plant terminology; the precooler at this plant operates like the cooler at other plants.

[d] Combined emissions from a precooler and cooler. Precooler emissions are vented to the scrubber while cooler emissions are vented directly to the atmosphere.

[e] Scrubber controls predryer and dryer emissions. (In the EPA test, 28% by mass of emissions are from the predryer.)

[f] Opacity reading is from the scrubber that controls the predryer and dryer.

[g] Plant L has two solids finishing trains.

computation of emissions since the emission rates were similar for all three runs. Due to particle collection problems, particle size data were invalid.

4.4.2 Low Density Prill Towers

EPA also tested one low density prill tower (Plant Z). This tower is equipped with a collection device and wetted fibrous filter scrubber to reduce emissions. The prill tower operating parameters at this plant, such as melt temperature, airflow, and prill temperature, are similar to other plants in the industry. Therefore, the tower operation can be considered representative of other low density plants. The collection device design used is proprietary, but functions similarly to others in the industry. This collection device captures 17 percent of the tower airflow and ducts it to a 3.5 kPa (14 in. W.G.) pressure drop wetted fibrous filter scrubber.[41]

EPA measured uncontrolled emissions of 0.39 g/kg (0.78 lb/ton) from this tower. These emissions contained both bypass emissions (0.22 g/kg (0.45 lb/ton)) and scrubber inlet emissions (0.16 g/kg (0.33 lb/ton)). The wetted fibrous filter scrubber reduced emissions collected by the collection device to 0.02 g/kg (0.04 lb/ton). When combined with bypass emissions, the total controlled emissions were 0.24 g/kg (0.48 lb/ton).[42]

The wetted fibrous filter scrubber removed 88 percent of the mass emissions received at its inlet. This value is less than the lowest removal efficiency reported by the manufacturer in Figure 4-3 (95 percent). The lower than expected removal efficiency is probably due to low particulate loadings (0.16 g/kg (0.33 lb/ton)). Also, particle sizes measured at the scrubber inlet indicate that approximately 50 percent of the particles were less than 1.2 microns (Figure 4-15). Even though the 88 percent removal efficiency is lower than expected, the scrubber is still effective in controlling AN emissions.

The total emissions reduction, including the bypass emissions, was only 38.5 percent. This low overall emissions reduction was probably due to the fact that the collection device only collected 41 percent of the uncontrolled emissions.

During the test, the process operation showed no anomalies and no sampling problems were reported.

4.4.3 Granulators

4.4.3.1 Drum Granulators. EPA tested uncontrolled and controlled emissions for only one granulator (Plant B). As stated in Section 3.2.4.1, all granulators in the industry are of the same design and operation. In addition, all granulation plants report using an entrainment scrubber to control granulator emissions. The entrainment scrubber tested at this plant has a 2.7 kPa (10.9 in. W.G.) pressure drop.[45]

Uncontrolled emissions measured for the granulator at Plant B were 147.2 g/kg (294.6 lb/ton). The entrainment scrubber reduced uncontrolled emissions to 0.22 g/kg (0.43 lb/ton), a 98 percent removal efficiency.[46] In Figure 4-16, the EPA's particle size test results are presented. The entrainment scrubber's removal of these particles corresponds with the manufacturer's efficiency curves presented in Figure 4-11.

The plant reported normal operation during testing. The only problem encountered during the test was excessive particulate loading at the inlet to the scrubber, which caused several test runs to be discontinuous.

4.4.3.2. Pan Granulator. The only pan granulator in operation in the AN industry was also tested by EPA. This facility (Plant D) uses a 6.75 kPa (27 in. W.G.) venturi scrubber to control emissions from the granulator and an evaporator.[7]

Uncontrolled emissions measured from the granulator were 1.34 g/kg (2.68 lb/ton).[48] The controlled pan granulator emissions could not be measured alone because the scrubber also controlled evaporator emissions. Nevertheless, controlled emissions were assumed to be from the granulator because it constituted 98 percent of the uncontrolled emissions. The total uncontrolled emissions were reduced from 1.37 g/kg (2.75 lb/ton) to 0.02 g/kg (0.04 lb/ton), which was a 98.5 percent removal efficiency.[48]

During the test, no abnormalities in process operation were reported. Cyclonic flow patterns were suspected at the scrubber inlet which resulted in measured volumetric flow rates to be 10-15 percent lower than actual volumetric flowrates. Since emissions calculations are based on volumetric flow rates, these too were believed to be low by 10-15 percent. Therefore, the calculated efficiencies were expected to be lower than actual efficiencies.

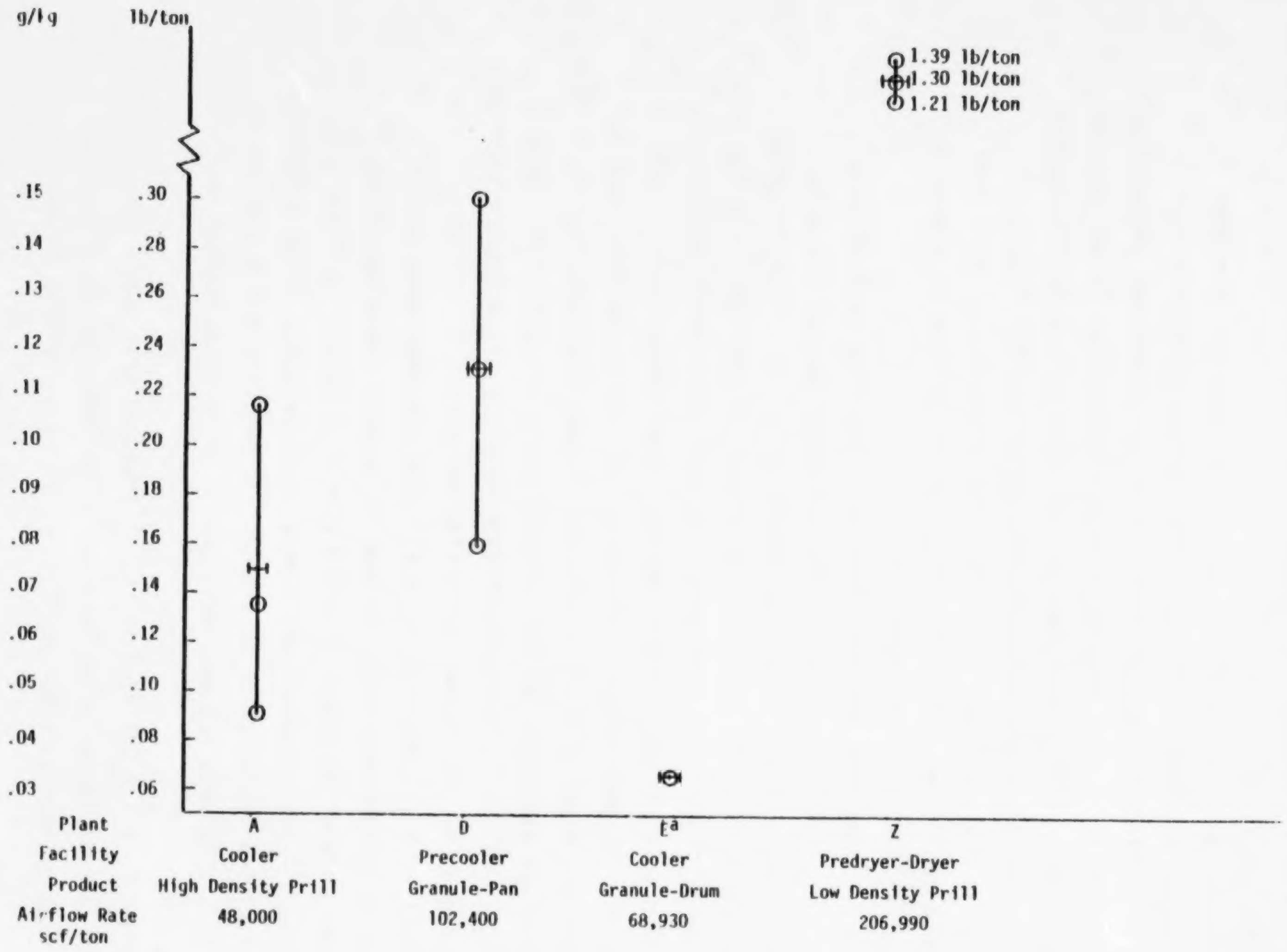
4.4.4 Solids Finishing

EPA tested the uncontrolled and controlled emissions for four solids finishing processes. The facilities tested included a high density prill rotary drum cooler (Plant A), a pan granulator rotary drum precooler (Plant D), a drum granulator rotary drum cooler (Plant E), and a low density prill rotary drum predryer and dryer (Plant Z). As stated in Section 4.3.5, these processes are considered together because of similarities in operation and emissions. The particle size data from each of these facilities are also similar, as can be seen in Figure 4-17 and Figures A-11 and A-12 in Appendix A.

Figure 4-18 presents the controlled emissions from each of these solids finishing facilities. All of the scrubbers reduced the emissions effectively because of the large size of the particles. Each scrubber, except the one at Plant A, had approximately 98 percent removal efficiency. The scrubber at Plant A had a 91 percent removal efficiency, which could be attributed to a low particulate loading. Even though its scrubber achieved a 99.5 percent removal efficiency, the controlled emissions for the predryer and dryer at Plant Z were much higher than the other facilities. The uncontrolled emissions for the predryer and dryer were also higher than the other solids finishing facilities possibly due to higher airflows; this may account for the higher controlled emissions.

At Plant A, a 1.0 kPa (4.0 in. W.G.) pressure drop spray chamber, followed by a cyclone separator, is used to control cooler emissions.[52] The scrubber reduced emissions from 0.8 g/kg (1.6 lb/ton) to 0.075 g/kg (0.15 lb/ton),[53] for a removal efficiency of 91 percent. Plant A reported no irregularities in operation or problems in sampling during the test. Particle size data were not available due to particulate collection problems.

At Plant D, a 1.4 kPa (5.6 in. W.G.) pressure drop spray scrubber is used to control precooler emissions.[54] The precooler at this plant operates like coolers at other facilities, since it follows the solids



[a] Only two test runs were accepted and both had the same emission rate.

Figure 4-18. Controlled emissions from solids finishing processes tested by EPA.

formation process. Uncontrolled emissions from the precooler measured 18 g/kg (36 lb/ton) and constituted 98 percent of the combined precooler-chain mill emissions. Controlled emissions were measured at 0.12 g/kg (0.23 lb/ton) and were considered to be from the precooler because of its proportion of the uncontrolled emissions. The scrubber showed a 99.4 percent removal efficiency. The plant operated normally and no problems occurred during the testing.[55]

A 3.3 kPa (13.1 in. W.G.) pressure drop entrainment scrubber is used at Plant E to control granulator cooler emissions.[56] The scrubber reduced uncontrolled emissions from 8.6 g/kg (17.3 lb/ton) to 0.03 g/kg (0.07 lb/ton), a 99.6 percent removal efficiency.[57]

During individual test periods at Plant E, variations in the cooler operation occurred; the cooler outlet air temperature and the cooler inlet and outlet solids temperature fluctuated. Problems also occurred during sampling because of excessive particulate loadings at the scrubber inlet, causing most of the sampling to be discontinuous. In test run 3, controlled emissions were measured higher than uncontrolled. A scrubber upset during the run may have caused some of these problems. Therefore, since the results of test run 3 were nontypical of the first two runs, only runs 1 and 2 were used in calculating the average.

Rotary drum predryer and dryer emissions at Plant Z are controlled by a tray scrubber. The uncontrolled and controlled mass emissions from these facilities were considerably higher than those at the other plants (see Table 4-3 and Figure 4-18), possibly because of their high airflows. EPA measured predryer-dryer uncontrolled emissions at 131 g/kg (262 lb/ton). These emissions were reduced to 0.65 g/kg (1.30 lb/ton) by the tray scrubber. This was a 99.5 percent removal efficiency.[58]

Particle sizes for the uncontrolled emissions from the predryer and dryer in Plant Z are presented in Appendix A. The controlled and uncontrolled emissions for each facility were presented earlier but will not be used in Chapter 5 to characterize uncontrolled and controlled emissions from solids finishing operations. These data are excluded because the high airflow rates and emissions reported for these operations were uncharacteristic of other tested solids finishing processes. However, even though the emission rate is abnormally high, the particles emitted from the predryer and dryer were large (99 percent by weight larger than 5 microns) and similar to the particle size data from the emissions of the other solids finishing facilities.

Plant Z operated normally during testing. Sampling problems occurred when high grain loadings caused plugging of the nozzles. To counteract this plugging, larger diameter nozzles were used, but the pumps were unable to draw a sufficient flow through the nozzles to maintain isokinetic sampling conditions. Low isokinetic sampling conditions would cause a bias in the mass flowrate calculations, resulting in higher than actual values. To compensate for the higher values, a second method (the area ratio method), was used with the concentration method to calculate mass flow rate. The average of these two was then used to obtain the mass flow rate.

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5.0 MODEL PLANTS AND CONTROL ALTERNATIVES

Model ammonium nitrate plants, existing levels of control and control alternatives are defined in this chapter. These model plants, existing control levels and control alternatives are used for analysis of the environmental and economic impacts associated with controlling particulate emissions from ammonium nitrate plants.

Model plants are defined in Section 5.1 and existing levels of control are discussed in Section 5.2. Section 5.3 presents control options, while Section 5.4 presents the control alternatives being considered and the emission parameters.

5.1 MODEL PLANTS

The model ammonium nitrate plants developed for this study are presented in Table 5-1. The rationale for selection of the model plants is discussed in Section 5.1.1. Process flowsheets and parameters for the model plants are presented in Section 5.1.2 and Section 5.1.3, respectively.

5.1.1 Rationale for Selection of Model Plants

Major solid production techniques currently in use in this industry are high density prilling, low density prilling and granulation. The emission sources included in a model high density prilling plant are the prill tower and cooler. Model low density prilling plant emission sources are the prill tower, predryer, dryer and cooler. Model granulation plants have two sources of emissions, granulators and coolers. Model plant production capacities range from 181 to 816 Mg/day (200 to 900 TPD) for low density prilling, and from 363 to 1089 Mg/day (400 to 1200 TPD) for both high density prilling and granulation plants.

Plant sizes were selected from the distribution of existing plant capacities to represent existing plants, as well as those expected to be constructed, modified or expanded in the near future. The data used to determine plant sizes, operating parameters and emissions levels were

TABLE 5-1. MODEL AMMONIUM NITRATE PLANTS

Model Plant #	Process	Capacity Mg/Day (TPD)	Emission Sources
H-1	High Density Prilling	363 (400)	Prill Tower, Rotary Drum Cooler
H-2	High Density Prilling	726 (800)	Prill Tower, Rotary Drum Cooler
H-3	High Density Prilling	1089 (1200)	Prill Tower, Rotary Drum Cooler
L-1	Low Density Prilling	181 (200)	Prill Tower; Rotary Drum Predryer, Dryer, and Cooler
L-2	Low Density Prilling	363 (400)	Prill Tower; Rotary Drum Predryer, Dryer, and Cooler
L-3	Low Density Prilling	816 (900)	Prill Tower; Rotary Drum Predryer, Dryer, and Cooler
G-1	Granulation	363 (400)	Rotary Drum Granulator, Rotary Drum Cooler
G-2	Granulation	726 (800)	Rotary Drum Granulator, Rotary Drum Cooler
G-3	Granulation	1089 (1200)	Rotary Drum Granulator, Rotary Drum Cooler

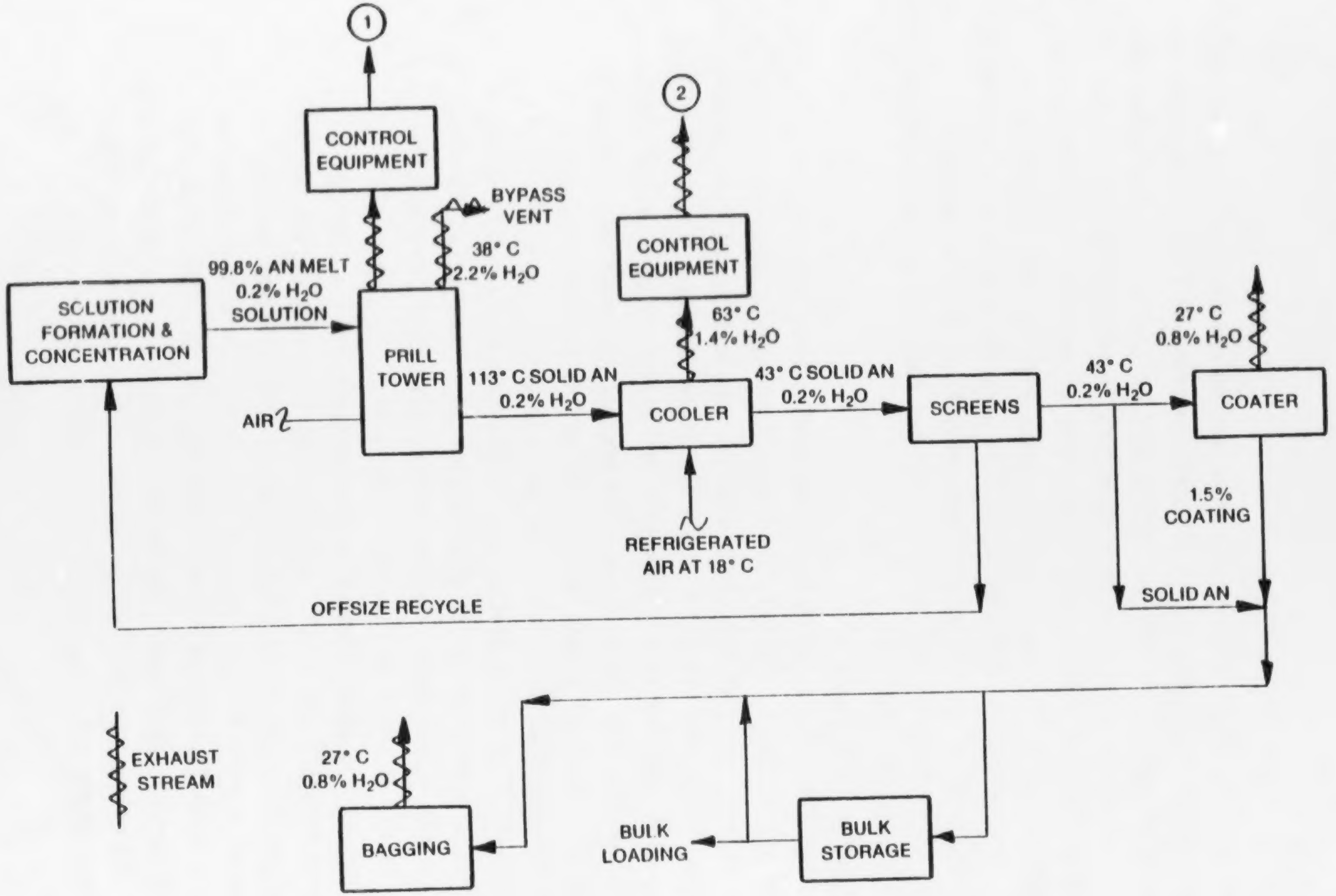
obtained from an industry survey, source testing and available literature.[1,2,3] The model plants represent plants of small, medium and large capacities. Although AN plants exist with greater capacities than the largest selected for modeling, their capacities were developed incrementally over several years; therefore, no model plants were chosen to represent those capacities. A few plants have prill towers producing both high and low density prills. However, there was insufficient information available to determine what the division of operating hours or production would be between products. Therefore, it was assumed that each model plant would produce a specific product only.

5.1.2 Process Flow Sheets

Process flow sheets for each of the model plants selected are presented in Figures 5-1 to 5-5. Figure 5-1 represents the high density prilling process. Figure 5-2 represents the low density prilling process, and Figures 5-3 to 5-5 represent the granulation process. These flow sheets present only the solids formation and finishing part of the plant downstream of the solution process. The process equipment and parameters shown for all the model plants are typical of the current industry practice and are based on a survey of the industry.

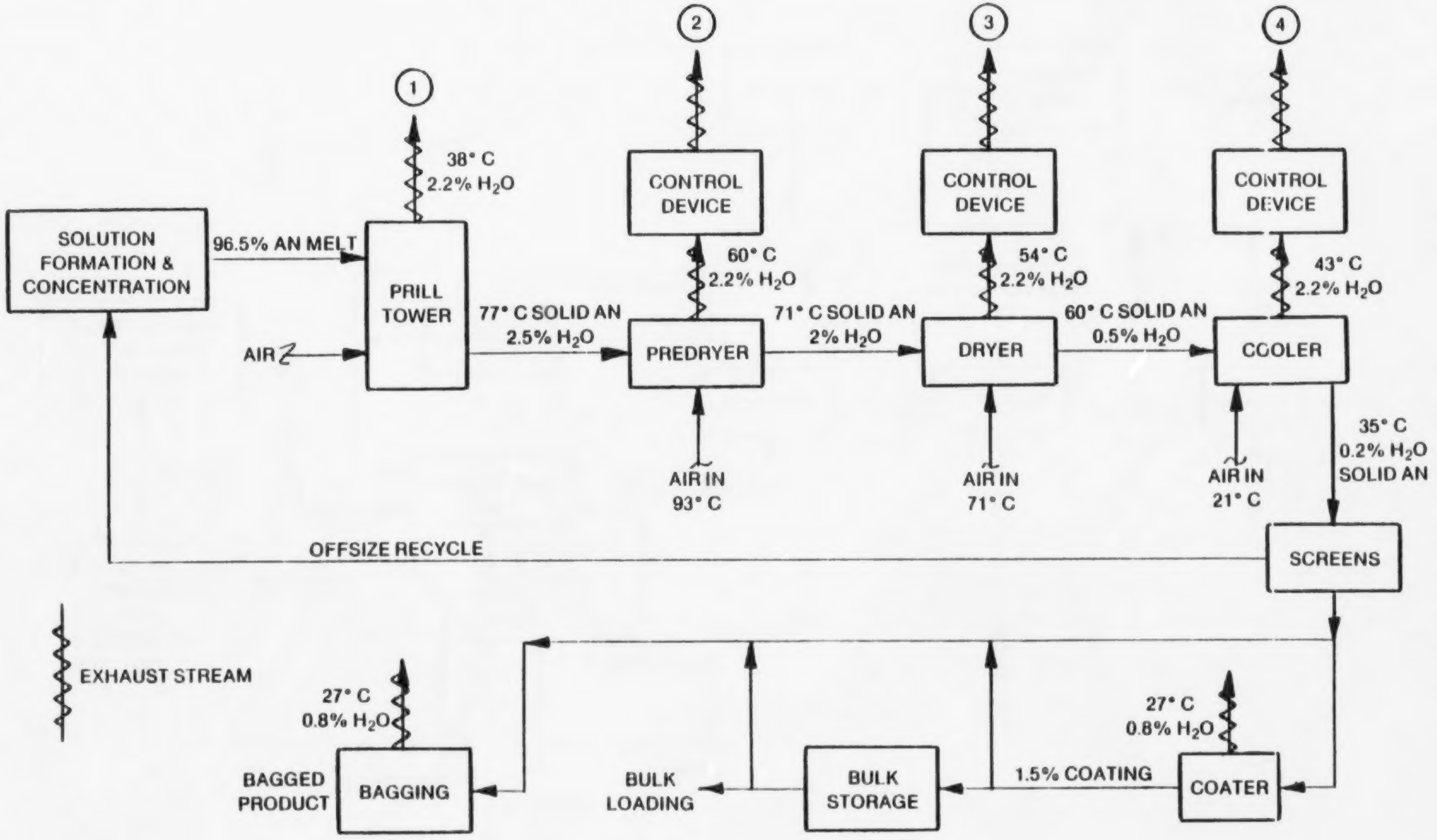
All sizes of prilling plants have flow sheets similar to the one shown. Rotary drum granulators usually come in a fixed size, 400 TPD. For plants with larger capacities, companies build multiple, parallel 400 TPD trains, as shown in Figures 5-3 to 5-5.

In each of the model plants, gaseous ammonia and a 56 percent nitric acid solution (by weight) are combined in a neutralizer to form an 83 percent solution of ammonium nitrate. This solution is then concentrated to a 96.5 to 99+ percent melt. Solids are then formed by prilling or granulation. After the formation process, the solids are dried, if needed, and cooled. The product may also be coated to prevent caking. The solids are then either bagged or bulk shipped. Additional process parameters are discussed in the following section.



1
CONTROL EQUIPMENT
BYPASS VENT
38° C
2.2% H_2O
99.8% AN MELT
0.2% H_2O
SOLUTION
SOLUTION FORMATION & CONCENTRATION
PRILL TOWER
AIR
113° C SOLID AN
0.2% H_2O
2
CONTROL EQUIPMENT
63° C
1.4% H_2O
COOLER
REFRIGERATED AIR AT 18° C
43° C SOLID AN
0.2% H_2O
SCREENS
43° C
0.2% H_2O
27° C
0.8% H_2O
COATER
1.5% COATING
SOLID AN
OFFSIZE RECYCLE
EXHAUST STREAM
27° C
0.8% H_2O
BAGGING
BULK LOADING
BULK STORAGE

Figure 5-1. High density prill plant.



①
②
③
④
38° C
2.2% H_2O
SOLUTION FORMATION & CONCENTRATION
96.5% AN MELT
PRILL TOWER
AIR
77° C SOLID AN
2.5% H_2O
CONTROL DEVICE
60° C
2.2% H_2O
PREDRYER
AIR IN
93° C
71° C SOLID AN
2% H_2O
CONTROL DEVICE
54° C
2.2% H_2O
DRYER
AIR IN
71° C
60° C SOLID AN
0.5% H_2O
CONTROL DEVICE
43° C
2.2% H_2O
COOLER
AIR IN
21° C
35° C
0.2% H_2O
SOLID AN
SCREENS
OFFSIZE RECYCLE
EXHAUST STREAM
27° C
0.8% H_2O
BAGGED PRODUCT
BAGGING
BULK LOADING
BULK STORAGE
1.5% COATING
27° C
0.8% H_2O
COATER

Figure 5-2. Low density prill plant.

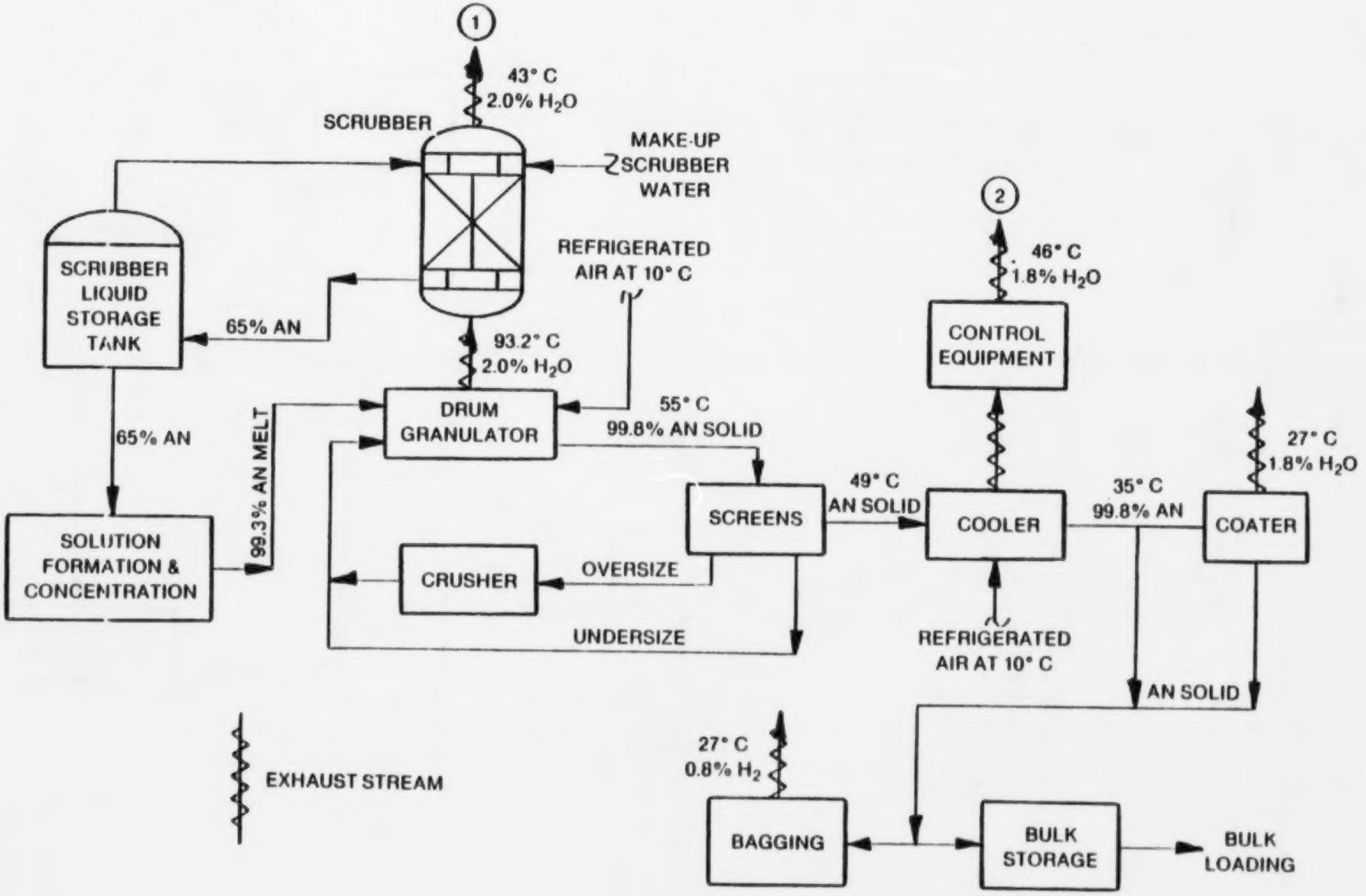

①
43° C
2.0% H_2O
SCRUBBER
MAKE-UP
SCRUBBER
WATER
REFRIGERATED
AIR AT 10° C
SCRUBBER
LIQUID
STORAGE
TANK
65% AN
93.2° C
2.0% H_2O
65% AN
99.3% AN MELT
DRUM
GRANULATOR
55° C
99.8% AN SOLID
SOLUTION
FORMATION &
CONCENTRATION
CRUSHER
OVERSIZE
SCREENS
UNDERSIZE
49° C
AN SOLID
②
46° C
1.8% H_2O
CONTROL
EQUIPMENT
COOLER
REFRIGERATED
AIR AT 10° C
35° C
99.8% AN
COATER
27° C
1.8% H_2O
AN SOLID
EXHAUST STREAM
27° C
0.8% H_2
BAGGING
BULK
STORAGE
BULK
LOADING

Figure 5-3. 363 Mg/day (400 TPD) granulation plant.

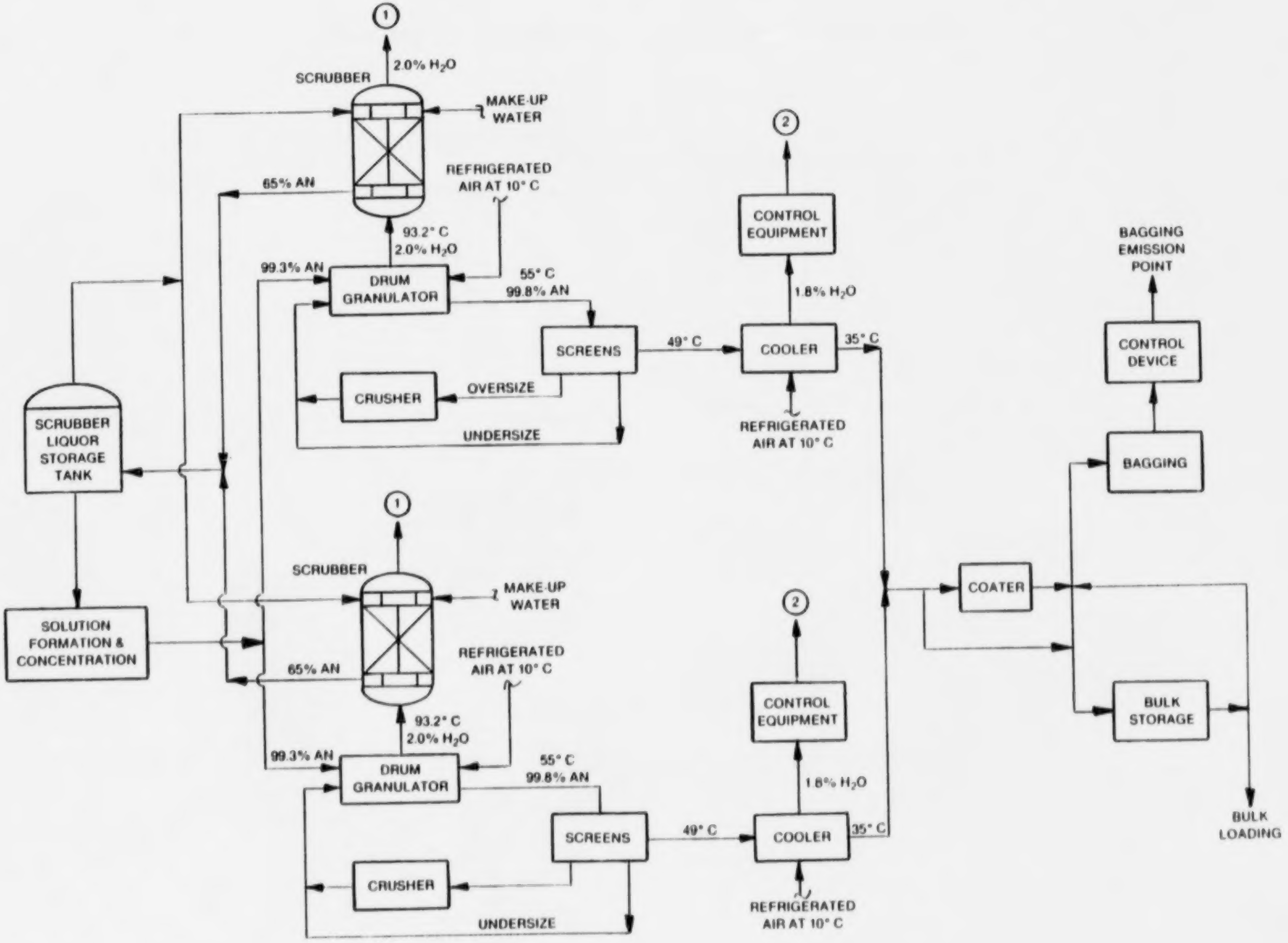

①
2.0% H_2O
SCRUBBER
MAKE-UP WATER
65% AN
REFRIGERATED AIR AT 10° C
93.2° C
2.0% H_2O
99.3% AN
DRUM GRANULATOR
55° C
99.8% AN
SCREENS
CRUSHER
OVERSIZE
UNDERSIZE
49° C
②
CONTROL EQUIPMENT
1.8% H_2O
COOLER
35° C
REFRIGERATED AIR AT 10° C
SCRUBBER LIQUOR STORAGE TANK
SOLUTION FORMATION & CONCENTRATION
①
SCRUBBER
MAKE-UP WATER
65% AN
REFRIGERATED AIR AT 10° C
93.2° C
2.0% H_2O
99.3% AN
DRUM GRANULATOR
55° C
99.8% AN
SCREENS
CRUSHER
UNDERSIZE
49° C
②
CONTROL EQUIPMENT
1.8% H_2O
COOLER
35° C
REFRIGERATED AIR AT 10° C
BAGGING EMISSION POINT
CONTROL DEVICE
BAGGING
COATER
BULK STORAGE
BULK LOADING

Figure 5-4. 726 Mg/day (800 TPD) granulation plant.

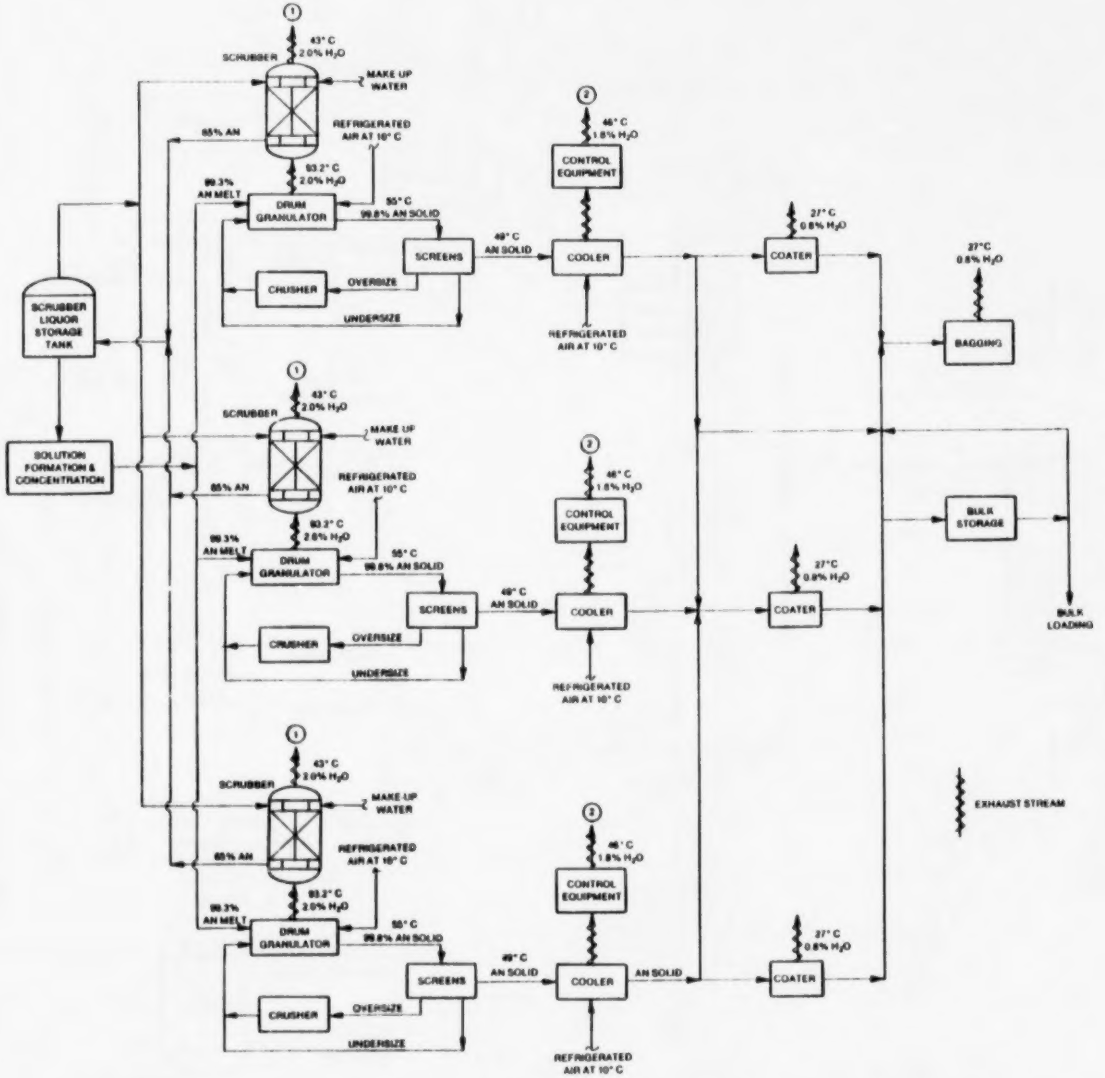

①
43° C
2.0% H₂O
SCRUBBER
MAKE UP WATER
REFRIGERATED AIR AT 10° C
65% AN
93.2° C
2.0% H₂O
99.3% AN MELT
DRUM GRANULATOR
55° C
99.8% AN SOLID
SCREENS
49° C
AN SOLID
CRUSHER
OVERSIZE
UNDERSIZE
②
46° C
1.8% H₂O
CONTROL EQUIPMENT
COOLER
REFRIGERATED AIR AT 10° C
27° C
0.8% H₂O
COATER
SCRUBBER LIQUOR STORAGE TANK
SOLUTION FORMATION & CONCENTRATION
①
43° C
2.0% H₂O
SCRUBBER
MAKE UP WATER
REFRIGERATED AIR AT 10° C
65% AN
93.2° C
2.0% H₂O
99.3% AN MELT
DRUM GRANULATOR
55° C
99.8% AN SOLID
SCREENS
49° C
AN SOLID
CRUSHER
OVERSIZE
UNDERSIZE
②
46° C
1.8% H₂O
CONTROL EQUIPMENT
COOLER
REFRIGERATED AIR AT 10° C
27° C
0.8% H₂O
COATER
①
43° C
2.0% H₂O
SCRUBBER
MAKE-UP WATER
REFRIGERATED AIR AT 10° C
65% AN
93.2° C
2.0% H₂O
99.3% AN MELT
DRUM GRANULATOR
55° C
99.8% AN SOLID
SCREENS
49° C
AN SOLID
CRUSHER
OVERSIZE
UNDERSIZE
②
46° C
1.8% H₂O
CONTROL EQUIPMENT
COOLER
AN SOLID
REFRIGERATED AIR AT 10° C
27° C
0.8% H₂O
COATER
27°C
0.8% H₂O
BAGGING
BULK STORAGE
BULK LOADING
EXHAUST STREAM

Figure 5-5. 1089 Mg/day (1200 TPD) granulation plant.

5.1.3 Process Parameters

Operating hours, raw material requirements, and base energy requirements for the model plants are presented below. These model plant parameters are based upon a survey of the industry and source test data.

The industry survey indicated a wide range of operating hours (less than 100 days/yr to 360 days/yr); however, these were influenced by market demand. All the model plants are assumed to operate 7728 hours per year, based on a 7 day, 24 hour/day, 46 week operation, which allows 6 weeks for scheduled and nonscheduled downtime.

The raw material requirements, ammonia, nitric acid, and coating material, for the model plants are presented in Table 5-2. Raw material requirements are the same for each plant of the same size, regardless of what product is produced, high density prills, low density prills or granules.

The greatest energy requirement for ammonium nitrate plants is the steam used to concentrate the 83 percent AN solution to the proper melt concentration. Electricity requirements for rotary equipment (granulators, predryers, dryers, and coolers), conveying equipment and pumps are small in comparison to the steam requirements. As a result, the energy requirements per unit of solid produced are approximately the same for all the model plants, approximately 5.12 GJ/Mg (4.4×10^6 Btu/ton) of solids produced.[4] This value includes the energy requirements for solution production and concentration, solids formation, finishing and handling, but does not include energy requirements for the concentration of scrubber liquors. Since the granulator scrubber is normally considered to be process equipment, the energy needed for the concentration of the granulator scrubber liquor must be included. The additional energy needed to concentrate this scrubber liquor is 0.272 GJ/Mg (2.34×10^5 Btu/ton) of ammonium nitrate produced. Plant energy requirements, along with impacts due to the control equipment, are presented in detail in Chapter 6.

TABLE 5-2. RAW MATERIAL REQUIREMENTS FOR THE MODEL AMMONIUM NITRATE PLANTS[3,a]

Plant Size		Ammonia		Nitric Acid[b]		Coating Agent	
Mg/day	TPD	Gg/yr	10^3 TPY	Gg/yr	10^3 TPY	Gg/yr	10^3 TPY
363	400	24.0	26.5	88.8	97.9	3.6	4.0
726	800	47.9	52.8	177.7	195.9	7.2	7.9
1089	1200	71.9	79.3	266.5	293.8	10.8	11.9

[a] Based on plant production capacity and 7728 operating hours per year.

[b] 56 percent nitric acid in water.

5.2 DETERMINATION OF EXISTING CONTROL LEVELS

Existing levels of control are used as a reference point in determining the impacts of control alternatives and options. This section presents the existing levels of control selected for the ammonium nitrate industry and the procedures used to select these levels. These levels were determined after a review of the emission level requirements and the degree of control imposed by State Implementation Plans (SIP's) and other regulations. This section is divided into two subsections: Subsection 5.2.1 presents a discussion of existing emission limitations. Subsection 5.2.2 discusses the existing degree of control found in the industry, and discusses the rationale for selection of controls to meet existing levels of control for each source.

5.2.1 Existing Emission Limitations

Twenty-three states contain plants that manufacture AN solids. Table 5-3 presents a summary of process weight particulate emission standards and maximum allowable particulate concentrations for these states. These regulations fall under the heading of "industrial source emissions". Only North Carolina has a specific regulation applying to chemical fertilizers. The regulation presented for California applies to the Orange County Air Pollution Control district, which accommodates the only AN solids production plant in California. Emission requirements vary significantly from state to state due to differences in process weight regulations, sampling techniques, source definition and enforcement methods.

Opacity regulations vary, but 17 of 23 states require emissions to be less than 20 percent opacity. This is the most stringent opacity regulation presently in effect. Four states allow a 40 percent opacity, while the remaining state, Illinois, adopted a 30 percent opacity regulation.

Discussion with plant and regulatory personnel indicate that opacity limits are frequently the most difficult to comply with. In some cases, regulatory agencies cited an opacity violation although particulate emission control was greater than that required to meet the mass emission level.

TABLE 5-3. EMISSIONS STANDARDS AFFECTING AMMONIUM NITRATE PLANTS

State	Opacity (percent)	Grains/ft^3	Grams/m^3	Process weight regulation $P \leq 30$ ton/hr	Process weight regulation $P > 30$ ton/hr	Allowable particulate emissions in lb/hr for 200 ton/day^a Process	Allowable particulate emissions in kg/hr for 181 Mg/day^a Process	Allowable particulate emissions in lb/hr for 1200 ton/day^a Process	Allowable particulate emissions in kg/hr for 1089 Mg/day^a Process
Alabama	20			$3.59(P)^{0.62}$	$17.31(P)^{0.16}$	13.37	6.079	32.37	14.72
Arizona	40			$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Arkansas[b]	20			$0.0722(P)^{0.78}$	$1.29(P)^{0.43}$	120.26	54.68	259.91	118.18
California[c]	20					26.74	12.14	13.15	5.97
Florida	20			$3.59(P)^{0.62}$	$17.31(P)^{0.16}$	13.37	6.079	32.37	14.72
Georgia	20			$3.59(P)^{0.62}$	$17.31(P)^{0.16}$	13.37	6.079	32.37	14.72
Illinois[d]	30			$2.54(P)^{0.534}$	$24.8(P)^{0.16}$	7.88	3.58	20.52	9.33
Indiana	40			$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Iowa	40			$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Kansas	20			$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Louisiana	20	0.3	0.69	$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Minnesota	20			$3.59(P)^{0.62}$	$17.31(P)^{0.16}$	13.37	6.079	32.37	14.72
Mississippi	40			$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Missouri	20	0.3	0.69	$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Nebraska	20			$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
New Mexico				$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
North Carolina	20			$9.377(P)^{0.3067}$		17.96	8.17	31.13	14.15
Oklahoma	20	0.3	0.69	$4.10(P)^{0.67}$	$(55.0(P)^{0.11})-40$	16.97	7.72	44.58	20.27
Tennessee	20	0.25	0.58	$3.59(P)^{0.62}$	$17.31(P)^{0.16}$	13.39	6.079	32.37	14.72
Texas	20			$3.12(P)^{0.985}$	$25.4(P)^{0.287}$	25.18	11.45	78.06	35.49
Utah	20			Under Development					
Washington	20	0.1	0.23	Under Development					
Wyoming	20			$3.59(P)^{0.62}$	$17.31(P)^{0.16}$	13.37	6.079	32.37	14.72

[a] Based on 24-hour operation.

[b] Process weight regulations for Arkansas apply to production rates of $100 \leq P < 10^4$ lb/hr and $10^4 \leq P < 10^6$ lbs/hr, respectively.

[c] Based on Los Angeles county APCD process weight rate table.

[d] Process weight regulations for Illinois apply to production rates of $P \leq 450$ tons/hr and $P \leq 450$ tons/hr, respectively.

Limits on particulate emissions from AN solids production facilities are usually based on the plant's production rate. Twenty-one of 23 plants are under process weight regulations, which vary between states (Table 5-3).

Another variation in the state emission regulations is the definition of the word "source". Most states consider each stack or process as a source; one state, Arkansas, considers the combined emissions of an entire plant as a source.

State air pollution standards may specify the sampling method for determining compliance with the emission standard. Specified sampling procedures include EPA's Method 5, the American Society of Mechanical Engineers' Performance Test Code (PTC) 27, and other procedures. The collection efficiencies of these sampling procedures can vary, depending upon factors such as the type of filter used, and the sample recovery and analytical procedures. Even when two state emission standards are identical, one standard can be more stringent if its sampling procedure collects a higher percentage of particulates.

The sampling and analytical procedure used by EPA to determine particulate emissions from ammonium nitrate plants during this study was developed to include condensible particulate emissions. The EPA method is a "modified" Method 5 described in Appendix B (AN-MOD 5). This modified version was developed because it was suspected that some ammonium nitrate particulates were being vaporized by the heated probe used in sample collection. In addition, Method 5 could not collect the small particulates formed by the recombination of ammonia and nitric acid fume. Because of differences in testing procedures, EPA test results and data from AN industry tests do not necessarily correlate.

There are several problems inherent in the use of SIP levels to determine the existing level of control for the AN industry. First, SIP's are usually enforced via opacity observations rather than actual measurement of emissions. No correlation between opacity and mass emissions has been made in the AN industry. Second, different test methods are used by the states to demonstrate compliance, and there is insufficient data to assess the magnitude of the differences between state test methods and the newly developed AN-MOD 5.

A new ammonium nitrate plant could be built in any state. Because it is difficult to predict where a new ammonium nitrate plant might be built, the emission standards for the states which presently contain AN plants were considered in the determination of the existing level of control. In addition, variances between monitoring methods and degree of enforcement were reviewed.

Table 5-4 was developed to characterize allowable emissions by plant size and location. From this table it can be seen that a new source would have to meet process weight regulations varying from 0.17 to 1.5 g/kg (0.34 to 3.0 lb/ton), excluding Arkansas, depending upon production rate and the state it is located in. It should be noted that fewer emissions are allowed as production increases.

To facilitate the selection of a representative existing level of control, both straight and weighted averages of the SIP's were determined. Arkansas was excluded because it utilizes a different definition of source. Weighted averages were determined for the total solid ammonium nitrate industry and for each of the three types of solids forming processes, high density prilling, low density prilling and granulation. The results showed agreement between the straight average, which ranged from 0.41 to 0.94 g/kg (0.82 to 1.88 lb/ton), and the weighted average for the total solids industry, which ranged between 0.4 to 0.94 g/kg (0.8 to 1.88 lb/ton). However, the weighted averages for the three solids forming processes showed differences between processes ranging from 0.37 to 1.16 g/kg (0.74 to 2.32 lb/ton). (See Table 5-4.)

A total of 33 plants located in 21 states were considered in Table 5-4. This is a small population which makes the weighted averages sensitive to low and high SIP levels. A survey of ammonium nitrate plants showed that most states contain a single ammonium nitrate production facility. A state containing several plants significantly affects any weighted averages by putting more emphasis on that state's SIP. Therefore, a straight average, not individual weighted averages, of the SIP's was

TABLE 5-4. ALLOWABLE EMISSIONS BY PLANT SIZE

PLANT SIZE	(200 TPD)	181 Mg/D	(400 TPD)	362 Mg/D	(800 TPD)	724 Mg/D	(1200 TPD)	1089 Mg/D
STATE	lb/ton	g/kg	lb/ton	g/kg	lb/ton	g/kg	lb/ton	g/kg
Alabama	1.604	.802	1.233	.616	.910	.455	.647	.323
Arizona	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Arkansas[a]	14.071	7.035	9.433	4.716	6.323	3.161	5.004	2.502
California	1.307	.6535	.793	.397	.466	.233	.343	.172
Florida	1.604	.802	1.233	.616	.910	.455	.647	.323
Georgia	1.604	.802	1.233	.616	.910	.455	.647	.323
Illinois	.946	.473	.685	.343	.496	.248	.410	.205
Indiana	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Iowa	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Kansas	2.037	1.018	1.620	.810	1.277	.613	.892	.446
Louisiana	2.037	1.018	1.620	.810	1.277	.613	.892	.446
Minnesota	1.604	.802	1.233	.616	.910	.455	.647	.323
Missouri	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Mississippi	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Nebraska	2.037	1.018	1.620	.810	1.227	.613	.892	.446
New Mexico	2.037	1.018	1.620	.810	1.227	.613	.892	.446
North Carolina	2.156	1.078	1.333	.667	.825	.413	.623	.312
Oklahoma	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Tennessee	2.037	1.018	1.620	.810	1.227	.613	.892	.446
Texas	3.022	1.511	2.991	1.49	2.085	1.042	1.561	.780
Wyoming	1.604	.802	1.233	.616	.910	.455	.647	.323
Straight Average	1.882	.941	1.498	.749	1.108	.554	.816	.408
TOTAL Weighted Average	1.884	.942	1.480	.74	1.089	.544	.795	.398
Low Density Prill Tower Weighted Average	1.894	.947	1.490	.745	1.094	.547	.797	.398
High Density Prill Tower Weighted Average	1.797	.899	1.375	.688	1.015	.507	.741	.370
GRANULATION Weighted Average	2.32	1.16	2.017	1.009	1.475	.737	1.086	.543

[a] Arkansas not included in averages because emissions are for entire plants, not single sources.

selected to determine the existing level of control. A survey of production levels for the solid ammonium nitrate industry indicated that an average plant produces 453 Mg/Day (500 TPD). Based on a straight average of the SIP's, a plant of this size would be required to meet an emission level of 0.7 g/kg (1.4 lb/ton) for each source. This emission level will be used as the basis for selecting the existing level of control for all of the sources.

5.2.2 Determination of Existing Emission Levels for Individual Sources

In this section, the existing level of control selected for each source being studied is presented. Uncontrolled emissions and the existing degree of control practiced by industry, which are summarized in Table 5-5, are also discussed. The existing level of control and corresponding control equipment selected for the various sources are presented in Table 5-6.

5.2.2.1 High Density Prill Towers. Based upon the industry data summarized in Table 5-5, uncontrolled emissions from high density prill towers range from 0.81 to 2.74 g/kg (1.63 to 5.48 lb/ton). The one high density prill tower tested by EPA had uncontrolled emissions of 1.6 g/kg (3.2 lb/ton). These uncontrolled emissions levels indicate that most prill towers would be required to utilize some degree of control under SIP's. Table 5-5 indicates that 15 percent utilize low efficiency scrubbers and 55 percent utilize collection hoods in conjunction with wetted fibrous filter scrubbers. The controls used are more effective than necessary to meet the range of SIP process weight regulations shown. (The extra degree of control may be attributed to the opacity requirements of the SIP's.)

Based on the existing degree of control practiced by industry, a new high density prill tower would require some degree of control. For the purpose of this analysis, an existing level of control of 0.7 g/kg (1.4 lb/ton) was chosen for high density prill towers (Table 5-6). This represents the allowable SIP level for an average size source. In addition, it was assumed that uncontrolled emissions for a high density

TABLE 5-5. UNCONTROLLED EMISSIONS AND EMISSIONS CONTROL TECHNIQUES FOR SOLID AMMONIUM NITRATE PROCESSING FACILITIES

Process	No. of Facilities	Uncontrolled Emissions Ammonium Nitrate g/kg (lb/ton) EPA	Uncontrolled Emissions Ammonium Nitrate g/kg (lb/ton) Industry	WFFS*	Entrainment	Cyclone	Venturi	Tray Type	Mechanical	Other[a]	None	No. Info.
Solids Formation												
High Density Prill Tower	20	1.6 (3.2)	0.82 - 2.74 (1.63 - 5.48)	11	-	-	1	1	-	4	3	-
Low Density Prill Tower	18	0.39 (0.78)	0.21 - 0.69 (0.42 - 1.38)	5	1	-	-	-	-	-	12	-
Drum Granulators	6	147.2 (294.6)	138 - 152 (277 - 305)	-	8	-	-	-	-	-	-	-
Pan Granulator	1	1.34 (2.68)	No Data	-	-	-	1	-	-	-	-	-
Solids Finishing												
Predryers, Dryers, Cooler	76[b]	0.83-18 (1.66-36)	3.2 - 35.2 (6.4 - 70.5)	1	7	37	-	7	12	2	3	3

a. Includes smog towers, knockout chambers, spray towers, internal controls, or wetted mesh pads.

b. Total number of solids finishing processes with available data. Some will have more than one control device or may be connected in series to a single control device.

*WFFS = Wetted Fibrous Filter Scrubber

TABLE 5-6. EXISTING LEVEL OF CONTROL (ELOC) EMISSIONS AND CONTROL EQUIPMENT FOR AMMONIUM NITRATE FACILITIES

Emission source	Existing control equipment	ELOC lb/ton	ELOC g/kg
High density prill tower	Two-tray Scrubber ΔP = 2.7 kPa (11" W.G.)	1.4	0.7
Low density prill tower	None	1.4	0.7
Granulator	Entrainment Scrubber ΔP = 3.5 kPa (14" W.G.)	0.5	0.25
Solids finishing	Tray Scrubber ΔP = 0.75 kPa (3" W.G.)	1.4	0.7

tower would be 1.55 g/kg (3.1 lb/ton), based upon the EPA test. With this level of uncontrolled emissions, a high density prill tower requires a low efficiency control device to meet the chosen emission level.

5.2.2.2 Low Density Prill Towers. Industry data summarized in Table 5-5 indicate that uncontrolled emissions for low density prill towers range from 0.21 to 0.69 g/kg (0.42 to 1.38 lb/ton) and that the majority of low density prill towers are uncontrolled. It is expected that new low density prill towers would have the same range of uncontrolled emissions and would be capable of meeting the applicable SIP's. The existing level of control chosen, 0.7 g/kg (1.4 lb/ton), represents the allowable SIP level for an average sized source. It is assumed that a new low density prill tower would not require any control equipment to achieve this emission level.

5.2.2.3 Granulators. Results of an EPA test show uncontrolled AN emissions of 147.2 g/kg (294.6 lb/ton) for granulators. A comparison of uncontrolled emissions from granulators and even the most lenient SIP's indicates that removal efficiencies of greater than 99 percent would be required. In addition, process economics dictate the use of a control device to recover the large amounts of product that would otherwise be lost. A survey of industry indicated that all existing granulators utilize wet scrubbers to control emissions. With these considerations in mind, it is unlikely that a new granulator will be built without some type of control device.

The existing level of control for granulators was set at 0.25 g/kg (0.5 lb/ton), based on an EPA test of a typical granulator scrubber (Table 5-6). This degree of control is greater than required by most SIP's; however, it is typical of existing industry practice.

5.2.2.4 Solids Finishing. Solids finishing includes granulator coolers, high density prill coolers, and low density predryers, dryers, and coolers. Rotary drum coolers, dryers and predryers have the same configuration no matter where they are applied. However, uncontrolled emissions from these rotary units do vary by the type of product handled.

All rotary coolers, dryers and predryers installed in the past ten years have been equipped with some form of control device. Wet scrubbers are the predominate control device in the industry. Three fluid bed coolers, one fluid bed dryer and one fluid bed predryer have been constructed over the last 11 years. Two of the three fluid bed coolers are uncontrolled.

Uncontrolled emissions for solids finishing operations are reported by industry to vary from 3.2 to 35.2 g/kg (6.4 to 70.5 lb/ton) and have been measured by EPA from 0.83 to 18 g/kg (1.66 to 36 lb/ton). With these high emissions levels, the majority of solids finishing operations would require some form of control to meet SIP's. Table 5-5 indicates that the majority of solids finishing operations are controlled. For the purpose of this analysis it was assumed that all solids finishing operations would have an existing level of control of 0.7 g/kg (1.4 lb/ton) based upon the average SIP's (Table 5-6). In addition, it was assumed that, based upon an average of EPA tests, the uncontrolled emissions for a typical solids finishing operation would be 5.4 g/kg (10.8 lb/ton). With this level of uncontrolled emissions, any solids finishing operation would require a moderately efficient scrubber to meet the chosen emission level.

5.3 CONTROL OPTIONS

This section presents an analysis of the individual emission sources requiring control. Discharge parameters from these sources are presented for the various model plants, and control equipment is selected to reduce emissions over the existing level of control. High density and low density prill towers are discussed in Sections 5.3.1 and 5.3.2, respectively. Section 5.3.3 discusses granulators, and Section 5.3.4 discusses solids finishing equipment.

5.3.1 High Density Prill Towers

The high density prill tower is usually controlled to meet state implementation plan (SIP) emission levels. A tray scrubber was chosen for the existing control device, as shown in Table 5-6. To meet a more stringent limitation, a fume collection hood, followed by a wetted fibrous filter scrubber, was selected (Option 1). Only the portion of the tower airflow having the most concentrated emissions is treated with the control device in this system. Another option selected was using the wetted fibrous filter scrubber to control the full tower airflow (Option 2). A third option was also selected and is the same as Option 2, except that the net tower airflow is reduced through the use of process modifications (Option 3). One plant in the industry operates in such a manner. This plant was originally designed to operate in the conventional manner, with full airflow. By modifying the process to handle a reduced airflow, the size and cost of control equipment were greatly reduced. Discharge parameters for high density prilling plants are presented in Tables 5-7a to 5-7c.

Control equipment is located on top of the prill tower in all cases except the full airflow case (Option 2). A scrubber that could handle the full tower airflow would be too large to fit on top of the prill tower. Therefore, the scrubber is located at ground level and tower emissions are ducted down to it.

5.3.2 Low Density Prill Towers

The low density prill tower is typically uncontrolled. Therefore, no control was selected for the existing case. One system for controlling particulate emissions from low density prill towers includes a fume collection hood, followed by a wetted fibrous filter scrubber (Option 1). With this system a selected portion of tower airflow emissions bypasses the control device. Another option chosen involves using the wetted fibrous filter scrubber to control the full tower airflow (Option 2). The discharge parameters for low density prilling plants are presented in Tables 5-8a to 5-8c.

The control equipment is located on top of the prill tower for all cases except the full airflow case for the same reasons as discussed above in 5.3.1.

5.3.3 Granulators

The granulator control device is the same for all control alternatives. All granulators in the industry are currently controlled with the same type of device (an entrainment scrubber), and if properly installed and

TABLE 5-7a. EMISSION PARAMETERS: AMMONIUM NITRATE HIGH DENSITY PRILLING PLANT - 363 Mg/Day (400 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate Emission Rate		Height of Discharge		Stack Diameter		Stack Temperature		Total Air Flow Rate		Air Velocity per Stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M³/min	ft/s	meters/s
Prill Tower	Stack	Existing	Tray Scrubber 11" ΔP	45.4	2.94	203.0	61.87	305.0	301.52	100	310.62	155,000	4,389.60	43.9	13.37
Prill Tower[a]	Stack	Option 1	Bypass	14.47	0.94	191.0	58.22	304.5	301.37	100	310.62	124,000	3,511.68	43.3	13.21
			Collection Hood/WFFS[b] 14" ΔP	1.73	0.11	220.0	67.06	4.0	1.22			31,000	877.92	41.1	12.53
Prill Tower	Stack	Option 2	14" ΔP WFFS[b]	3.24	0.21	60.0	18.29	206.0	201.83	100	310.62	155,000	4,389.60	45.7	13.93
Prill Tower[c]	Stack	Option 3	14" ΔP WFFS[b]	3.24	0.21	222.0	67.67	4.5	1.37	100	310.62	39,000	1,104.48	41.0	12.50
Cooler	Stack	Existing	Tray Scrubber	45.4	2.94	60.0	18.29	3.0	0.91	115	318.94	20,000	566.40	47.2	14.39
Cooler	Stack	Option 1	Entrainment	3.24	0.21	60.0	18.29	3.0	0.91	115	318.94	20,000	566.40	47.2	14.39

[a] 20 percent of the airflow goes through collection hood; 87 percent of the emissions goes through collection hood.

[b] Wetted fibrous filter scrubber.

[c] Reduced flow -- 25 percent of baseline.

TABLE 5-7b. EMISSION PARAMETERS: AMMONIUM NITRATE HIGH DENSITY PRILLING PLANT - 726 Mg/Day (800 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate Emission Rate		Height of Discharge		Stack Diameter		Stack Temperature		Total Air Flow Rate		Air Velocity per Stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M³/min	ft/s	meters/s
Prill Tower	Stack	Existing	Tray Scrubber 11" ΔP	90.7	5.88	205.0	62.48	406.0	401.83	100	310.62	310,000	8,779.20	45.7	13.93
Prill Tower[a]	Stack	Option 1	Bypass	28.93	1.88	195.0	59.44	306.0	301.83	100	310.62	248,000	7,023.36	48.8	14.86
			Collection Hood/WFFS[b] 14" ΔP	3.47	0.23	224.0	68.28	5.5	1.68			62,000	1,755.84	43.5	13.26
Prill Tower	Stack	Option 2	14" ΔP WFFS[b]	6.48	0.42	60.0	18.29	406.0	401.83	100	310.62	310,000	8,779.20	45.7	13.93
Prill Tower	Stack	Option 3	14" ΔP WFFS[b]	6.48	0.42	225.0	68.58	6.0	1.83	100	310.62	78,000	2,208.96	46.0	14.02
Cooler	Stack	Existing	Tray Scrubber	90.7	5.88	80.0	24.38	5.0	1.52	115	318.94	40,000	1,132.80	33.97	10.35
Cooler	Stack	Option 1	Entrainment Scrubber 13" ΔP	6.48	0.42	80.0	24.38	5.0	1.52	115	318.94	40,000	1,132.80	33.97	10.35

[a] 20 percent of the airflow goes through collection hood; 87 percent of the emission goes through hood.

[b] Wetted fibrous filter scrubber.

[c] Reduced flow - 25 percent of baseline.

TABLE 5-7c. EMISSION PARAMETERS: AMMONIUM NITRATE HIGH DENSITY PRILLING PLANT - 1089 Mg/Day (1200 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate Emission Rate		Height of Discharge		Stack Diameter		Stack Temperature		Total Air Flow Rate		Air Velocity per Stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M³/min	ft/s	meters/s
Prill Tower	Stack	Existing	Tray Scrubber 11" ΔP	136.1	8.82	205.0	62.48	606.0	601.83	100	310.62	465,000	13,168.80	45.7	13.93
Prill Tower[a]	Stack	Option 1	Bypass	43.41	2.81	195.0	59.44	506.0	501.83	100	310.62	372,000	10,535.04	43.9	13.37
			Collection Hood/WFFS[b] 14" ΔP	5.20	0.34	222.0	67.67	204.5	201.37			93,000	2,633.76	48.8	14.86
Prill Tower	Stack	Option 2	14" ΔP WFFS[b]	9.72	0.63	60.0	18.29	606.0	601.83	100	310.62	465,000	13,168.80	45.7	13.93
Prill Tower[c]	Stack	Option 3	14" ΔP WFFS[b]	9.72	0.63	223.0	67.97	205.0	201.52	100	310.62	116,000	3,285.12	49.3	15.01
Cooler	Stack	Existing	Tray Scrubber	136.1	8.82	90.0	27.43	6.0	1.83	115	318.94	60,000	1,699.20	35.4	10.79
Cooler	Stack	Option 1	Entrainment Scrubber 13" ΔP	24.3	1.58	90.0	27.43	6.0	1.83	115	318.94	60,000	1,699.20	35.4	10.79

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[a] 20 percent of the airflow goes through collection hood; 87 percent of the emission goes through collection hood.

[b] Wetted fibrous filter scrubber.

[c] Reduced flow -- 25 percent of baseline.

TABLE 5-8a. EMISSION PARAMETERS: AMMONIUM NITRATE LOW DENSITY PRILLING PLANT - 181 Mg/Day (200 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate emission rate grains/s	Particulate emission rate grams/s	Height of discharge feet	Height of discharge meters	Stack diameter feet	Stack diameter meters	Stack temperature °F	Stack temperature K	Total Air flow rate scfm	Total Air flow rate Std M³/min	Air velocity per stack ft/s	Air velocity per stack meters/s
Prill Tower	Stack	Existing	Uncontrolled	22.7	1.47	189.0	57.61	3@ 3.5	3@ 1.07	100	310.62	76,000	2152.32	43.9	13.38
Prill Tower[a]	Stack	Option 1	Bypass	7.23	0.47	188.0	57.30	3@ 3.0	3@ 0.91	100	310.62	61,000	1727.52	48.0	14.62
			Collection Hood/WFFS[b] 14" ΔP	0.87	0.06	218.0	66.45	3.0	0.91			15,000	424.80	35.4	10.79
Prill Tower	Stack	Option 2	14" ΔP WFFS[b]	1.62	0.11	60.0	18.29	6.0	1.83	100	310.62	76,000	2152.32	44.8	13.66
Predryer	Stack	Existing	Tray Scrubber	22.7	1.47	50.0	15.24	2.0	0.61	135	330.04	10,000	283.20	53.0	16.15
Predryer	Stack	Option 1	Entrainment wet scrubber 13" ΔP	1.62	0.11	50.0	15.24	2.0	0.61	135	330.04	10,000	283.20	53.0	16.15
Dryer	Stack	Existing	Tray Scrubber	22.7	1.47	50.0	15.24	2.0	0.61	135	330.04	10,000	283.20	53.0	16.15
Dryer	Stack	Option 1	Entrainment wet scrubber 13" ΔP	1.62	0.11	50.0	15.24	2.0	0.61	135	330.04	10,000	283.20	53.0	16.15
Cooler	Stack	Existing	Tray Scrubber	22.7	1.47	50.0	15.24	2.0	0.61	115	318.94	10,000	283.20	53.0	16.15
Cooler	Stack	Option 1	Entrainment wet scrubber 13" ΔP	1.62	0.11	50.0	15.24	2.0	0.61	115	318.94	10,000	283.20	53.0	16.15

[a] 20 percent of the total airflow goes through collection device; 80 percent of the emissions go through collection device.

[b] Wetted Fibrous Filter Scrubber

TABLE 5-8b. EMISSION PARAMETERS: AMMONIUM NITRATE LOW DENSITY PRILLING PLANT - 363 Mg/Day (400 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate emission rate		Height of discharge		Stack diameter		Stack temperature		Total Air flow rate		Air velocity per stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M^3/min	ft/s	meters/s
Prill Tower	Stack	Existing	Uncontrolled	45.4	2.94	193.0	58.83	3@5.0	3@1.52	100	310.62	152,000	4304.64	43.0	13.11
Prill Tower[a]	Stack	Option 1	Bypass	14.47	0.94	191.0	58.22	3@4.5	3@1.37	100	310.62	122,000	3455.04	42.6	13.00
			Collection Hood/WFFS[b] 14" ΔP	1.73	0.11	220.0	67.06	4.0	1.22			30,000	849.60	39.8	12.13
Prill Tower	Stack	Option 2	14" ΔP WFFS[b]	3.24	0.21	60.0	18.29	2@6.0	2@1.83	100	310.62	152,000	4304.64	44.8	13.66
Predryer	Stack	Existing	Tray Scrubber	45.4	2.94	60.0	18.29	3.0	0.91	135	330.04	20,000	566.40	47.2	14.39
Predryer	Stack	Option 1	Entrainment wet scrubber 13" ΔP	3.24	0.21	60.0	18.29	3.0	0.91	135	330.04	20,000	566.40	47.2	14.39
Dryer	Stack	Existing	Tray Scrubber	45.4	2.94	60.0	18.29	3.0	0.91	135	330.04	20,000	566.40	47.2	14.39
Dryer	Stack	Option 1	Entrainment wet scrubber 13" ΔP	3.24	0.21	60.0	18.29	3.0	0.91	135	330.04	20,000	566.40	47.2	14.39
Cooler	Stack	Existing	Tray Scrubber	45.4	2.94	60.0	18.29	3.0	0.91	115	318.94	20,000	566.40	47.2	14.39
Cooler	Stack	Option 1	Entrainment wet scrubber 13" ΔP	3.24	0.21	60.0	18.29	3.0	0.91	115	318.94	20,000	566.40	47.2	14.39

[a] 20 percent of total airflow goes through collection hood; 80 percent of emission goes through collection hood.

[b] Wetted fibrous filter scrubber.

TABLE 5-8c. EMISSION PARAMETERS: AMMONIUM NITRATE LOW DENSITY PRILLING PLANT - 816 Mg/Day (900 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate emission rate		Height of discharge		Stack diameter		Stack temperature		Total Air flow rate		Air velocity per stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M^3/min	ft/s	meters/s
Prill Tower	Stack	Existing	Uncontrolled	102.1	6.62	195.0	59.44	406.0	401.83	100	310.62	342,000	9,685.44	50.4	15.37
Prill Tower[a]	Stacks	Option 1	Bypass	32.6	2.11	195.0	59.44	306.0	301.83	100	310.62	274,000	7,759.68	53.9	16.43
			Collection Hood/WFFS[b] 14" ΔP	3.90	0.25	225.0	68.58	6.0	1.83			68,000	1,925.76	40.1	12.22
Prill Tower	Stacks	Option 2	14" ΔP WFFS[b]	7.29	0.47	60.0	18.29	406.0	401.83	100	310.62	342,000	9,685.44	50.4	15.37
Predryer	Stack	Existing	Tray Scrubber	102.1	6.62	80.0	24.38	5.0	1.52	135	330.04	45,000	1,274.40	38.2	11.64
Predryer	Stack	Option 1	Entrainment wet scrubber 13" ΔP	7.29	0.47	80.0	24.38	5.0	1.52	135	330.04	45,000	1,274.40	38.2	11.64
Dryer	Stack	Existing	Tray Scrubber	102.1	6.62	80.0	24.38	5.0	1.52	135	330.04	45,000	1,274.40	38.2	11.64
Dryer	Stack	Option 1	Entrainment wet scrubber 13" ΔP	7.29	0.47	80.0	24.38	5.0	1.52	135	330.04	45,000	1,274.40	38.2	11.64
Cooler	Stack	Existing	Tray Scrubber	102.1	6.62	80.0	24.38	5.0	1.52	115	318.94	45,000	1,274.40	38.2	11.64
Cooler	Stack	Option 1	Entrainment wet scrubber 13" ΔP	7.29	0.47	80.0	24.38	5.0	1.52	115	318.94	45,000	1,274.40	38.2	11.64

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[a] 20 percent of total airflow goes through collection device; 80 percent of the emissions goes through collection device.

[b] Wetted fibrous filter scrubber.

operated, should have similar emissions. In addition, there is no other industry data available to indicate whether another type of control device would be more applicable or give better performance on granulator emissions. The discharge parameters for granulation plants are presented in Tables 5-9a to 5-9c.

5.3.4 Predryers, Dryers and Coolers

For all rotary drum predryers, dryers and coolers, the existing control is a tray scrubber, as shown in Table 5-6. An entrainment scrubber with a 3.25 kPa (13 in. W.G.) pressure drop has been selected as a control option for these facilities. EPA measured particulate emissions at the inlet and outlet of an entrainment scrubber applied to the rotary drum cooler of a drum granulation plant. The entrainment scrubber proved effective in controlling emissions from this source. EPA also tested a predryer, dryer and cooler at a low density plant and a cooler at a high density plant. Emissions from all these facilities were found to be similar in character; therefore, the entrainment scrubber is considered capable of reducing emissions to the same level when applied to each of these facilities. For the low density prilling process, individual control alternatives for predryers, dryers and coolers will not be considered, since the emissions are similar and all plants within the industry control all three processes. No case was identified in the industry where one or two of these processes were controlled and not the other(s). The discharge parameters for these facilities are presented, with their respective solid formation facilities, in Tables 5-7, 5-8 and 5-9.

5.4 CONTROL ALTERNATIVES

This section presents control alternatives applied to ammonium nitrate solids formation and finishing equipment. These control alternatives were developed by combining the various control options presented in the previous section. Control alternatives have been developed for high density prilling, low density prilling and granulation plants. The environmental and economic impacts associated with these alternatives will be evaluated in Chapters 6 and 7.

TABLE 5-9a. EMISSION PARAMETERS: AMMONIUM NITRATE GRANULATION PLANT - 363 Mg/Day (400 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate emission rate		Height of discharge		Stack diameter		Stack temperature		Total Air flow rate		Air velocity per stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M^3/min	ft/s	meters/s
Granulator	Stack	Existing & Option 1	Entrainment Scrubber 14" ΔP	16.2	1.05	90.0	27.43	6.0	1.83	110	316.17	40,000	1,132.80	23.6	7.19
Cooler	Stack	Existing	Tray Scrubber	45.4	2.94	60.0	18.29	3.0	0.91	115	318.94	20,000	566.40	47.2	14.39
Cooler	Stack	Option 1	Entrainment Scrubber 13" ΔP	3.24	0.21	60.0	18.29	3.0	0.91	115	318.94	20,000	566.40	47.2	14.39

TABLE 5-9b. EMISSION PARAMETERS: AMMONIUM NITRATE GRANULATION PLANT - 726 Mg/Day (800 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate emission rate		Height of discharge		Stack diameter		Stack temperature		Total Air flow rate		Air velocity per stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M^3/min	ft/s	meters/s
Granulator	Stack	Existing & Option 1	Entrainment Scrubber 14" Δ P	32.4	2.10	20 90.0	20 27.43	20 6.0	20 1.83	110	316.17	80,000	2,265.60	23.6	7.19
Cooler	Stack	Existing	Tray Scrubber	90.7	5.88	20 60.0	20 18.29	20 3.0	20 0.91	115	318.94	40,000	1,132.80	47.2	14.39
Cooler	Stack	Option 1	Entrainment Scrubber 13" Δ P	6.48	0.42	20 60.0	20 18.29	20 3.0	20 0.91	115	318.94	40,000	1,132.80	47.2	14.39

TABLE 5-9c. EMISSION PARAMETERS: AMMONIUM NITRATE GRANULATION PLANT - 1,089 Mg/Day (1,200 TONS PER DAY)

Emission Source	Type of Discharge	Level of Control	Type of Control	Particulate emission rate		Height of discharge		Stack diameter		Stack temperature		Total Air flow rate		Air velocity per stack	
				grains/s	grams/s	feet	meters	feet	meters	°F	K	scfm	Std M³/min	ft/s	meters/s
Granulator	Stack	Existing & Option 1	Entrainment Scrubber 14"ΔP	48.6	3.15	30 90.0	30 27.43	30 6.0	30 1.83	110	316.17	120,000	3,398.40	23.6	7.19
Cooler	Stack	Existing	Tray Scrubber	136.1	8.82	30 60.0	30 18.29	30 3.0	30 0.91	115	318.94	60,000	1,699.20	47.2	14.39
Cooler	Stack	Option 1	Entrainment Scrubber 13"ΔP	9.72	0.63	30 60.0	30 18.29	30 3.0	30 0.91	115	318.94	60,000	1,699.20	47.2	14.39

The first control alternative (Alternative No. 1) for each model plant was chosen to represent the existing level of control (ELOC), as described in Section 5.2.2. This alternative is used as a basis of comparison for the other alternatives. The remaining alternatives were determined by selectively applying more efficient emission control techniques than the existing control to the facilities in the model plants. Typically, Alternative No. 2 for each model plant applies more efficient emission control equipment to the facility with the largest emissions. Subsequent alternatives are then selected with successively smaller emissions. This procedure allows an incremental determination of the impacts associated with applying possible alternatives to individual facilities within the model plants. Table 5-10 presents combinations of existing and optional controls applied to the processing facilities for the various control alternatives.

The existing level of control (ELOC), Alternative No. 1, was presented in Table 5-6. As discussed in Chapter 4, a variety of emission control devices are used to control emissions from the various facilities. The control devices and the emission factors selected for the various control options are summarized in Table 5-11. The emission control devices used in the various control alternatives are detailed in Table 5-12 for all the model plants.

TABLE 5-10. CONTROL ALTERNATIVES FOR AMMONIUM NITRATE PLANTS

HIGH DENSITY PRILLING PROCESS

Alternative Number	Prill Tower	Cooler
1 (existing)	0	0
2	0	X
3	X (option 1)	X
4	X (option 2)	X
4a	X (option 3)	X

LOW DENSITY PRILLING PROCESS

Alternative Number	Prill Tower	Predryer, Dryer and Cooler
1 (existing)	0	0
2	0	X
3	X (option 1)	X
4	X (option 2)	X

GRANULATION PROCESS

Alternative Number	Granulator	Cooler
1 (existing)	0-X*	0
2	0-X*	X

0 - Existing Control
X - Optional Control

*Granulators existing and option control are the same.

TABLE 5-11. EMISSION FACTORS

	Uncontrolled		Existing Control	Existing		Control Option Equipment	Controlled	
	kg/Mg	(lbs/ton)		kg/Mg	(lbs/ton)		kg/Mg	(lbs/ton)
Solids Formation								
Low Density Prill Towers	0.7	(1.4)	None	0.7	(1.4)	Option 1 Collection Hood/WFFS[a] 3.5 kPa (14" W.G.) ΔP	0.25	(0.5)
						Option 2 WFFS[a] 3.5 kPa (14" W.G.) ΔP	0.05	(0.1)
High Density Prill Towers	1.55	(3.1)	Two-Tray Scrubber 2.75 kPa (11" W.G.) ΔP	0.7	(1.4)	Option 1[5] Collection Hood/WFFS[a] 3.5 kPa (14" W.G.) ΔP	0.25	(0.5)
						Option 2 and 3[5] WFFS[a] 3.5 kPa (14" W.G.) ΔP	0.05	(0.1)
Granulators	145	(290)	Entrainment Scrubber 3.5 kPa (14" W.G.) ΔP	0.25	(0.5)	Same	0.25	(0.5)
Solids Finishing								
Predryers, Dryer, Cooler	5.4*	(10.8)*	Tray Scrubber .75 kPa (3" W.G.) ΔP	0.7	(1.4)	Entrainment Scrubber 3.25 kPa (13" W.G.) ΔP	0.05	(0.1)

[a] Wetted Fibrous Filter Scrubber
*Average of EPA test data

TABLE 5-12. CONTROL ALTERNATIVES FOR MODEL AMMONIUM NITRATE PLANTS

			Type of Control Device on Facilities	
Model Plant # - Alternative #	Process	Capacity Mg/Day (TPD)	Prill Tower or Granulator	Predryer, Dryer or Cooler
H1-1	High Density Prilling	363 (400)	Tray Scrubber	Tray Scrubber
H1-2	High Density Prilling	363 (400)	Tray Scrubber	Entrainment Scrubber
H1-3	High Density Prilling	363 (400)	Collection Hood/WFFS[a] (Op.1)	Entrainment Scrubber
H1-4	High Density Prilling	363 (400)	Full Flow WFFS[a] (Op.2)	Entrainment Scrubber
H1-4a	High Density Prilling	363 (400)	Reduced Flow WFFS[a] (Op.3)	Entrainment Scrubber
H2-1 through H2-4a	High Density Prilling	726 (800)	Same controls as used on Alternatives H1-1 through H1-4a.	
H3-1 through H3-4a	High Density Prilling	1089 (1200)	Same controls as used on Alternatives H1-1 through H1-4a.	
L1-1	Low Density Prilling	181 (200)	None	Tray Scrubber
L1-2	Low Density Prilling	181 (200)	None	Entrainment Scrubber
L1-3	Low Density Prilling	181 (200)	Collection Hood/WFFS[a] (Op.1)	Entrainment Scrubber
L1-4	Low Density Prilling	181 (200)	Full Flow WFFS[a] (Op.2)	Entrainment Scrubber
L2-1 through L2-4	Low Density Prilling	363 (400)	Same controls as used on Alternatives L1-1 through L1-4.	
L3-1 through L3-4	Low Density Prilling	816 (900)	Same controls as used on Alternatives L1-1 through L1-4.	
G1-1	Granulation	363 (400)	Entrainment Scrubber	Tray Scrubber
G1-2	Granulation	363 (400)	Entrainment Scrubber	Entrainment Scrubber
G1-1 and G2-2	Granulation	726 (800)	Same controls as used on Alternatives G1-1 and G1-2.	
G3-1 and G3-2	Granulation	1089 (1200)	Same controls as used on Alternatives G1-1 and G1-2.	

[a] Wetted Fibrous Filter Scrubber

5.5 REFERENCES

1. Memo from Anderson, C. D., Radian Corporation, to file. July 2, 1980. 27 p. Tabular summary of information received from the ammonium nitrate industry.

2. Memo from Bowen, M., Radian Corporation, to file. October 11, 1980. 6 p. Table summarizing source test data obtained under this study.

3. Search, W. J. and R. B. Reznick (Monsanto Corporation) Source Assessment: Ammonium Nitrate Production. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, N. C. Publication No. EPA-600/2-77-107. September 1977. 78 p.

4. Lowenheim, F. A. and M. K. Mosan, Industrial Chemicals, 4th Edition. New York, John Liley and Sons, 1975. pp. 97-102.

5. Memo from Apple, C., Radian Corporation, to file. October 22, 1980. 11 p. Support for high density prill tower emission factors.

6.0 ENVIRONMENTAL IMPACTS

This chapter discusses the environmental impacts associated with each of the control alternatives for particulate emissions in the solid ammonium nitrate (AN) manufacturing industry. Emission sources to be considered are low and high density prill towers, granulators and solids finishing operations (predryers, dryers, coolers). The air pollution, water pollution, solid waste and energy impacts associated with the control alternatives are identified and discussed in Sections 6.1 to 6.4, respectively. Other impacts are evaluated in Section 6.5. All impacts are based on the model plant parameters presented in Chapter 5.

6.1 AIR POLLUTION IMPACT

The impact of each control alternative on air quality is presented in this section. Two impacts are considered: primary impacts, or the reduction of particulates due to the application of the control options and secondary impacts due to pollutants generated as a result of applying the control equipment.

6.1.1 Primary Air Quality Impacts

Table 6-1 presents total plant emission factors for each model plant and control alternative outlined in Chapter 5. The reduction in emissions over the existing level of control (ELOC) due to the application of the control options, is also presented here. The impacts of the ELOC (primary emissions, secondary emissions, energy requirements, etc.) are used as a reference value to compare the impacts of the control alternatives. The remaining alternatives provide increasing levels of control. These emission levels are presented on a mass per unit production basis, so that emission levels for any plant operating under conditions similar to the model plant can be estimated. The largest reduction in emissions, 2.6 g/kg (5.2 lb/ton) of AN produced, occurs for Alternative 4 on low

TABLE 6-1. EMISSION FACTORS AND REDUCTIONS FOR CONTROL ALTERNATIVES

Model Plant Number		Control Alternative	Prill Tower	Cooler	Emission Factor[a] g/kg	Emission Factor[a] lb/ton	Reduction beyond ELOC g/kg	Reduction beyond ELOC lb/ton	Reduction beyond ELOC percent
H-1-3	High Density Prilling	1 (ELOC)	0	0	1.40	(2.80)	-	-	0
		2	0	X	0.75	(1.50)	0.65	(1.30)	46
		3	X (Option 1)	X	0.30	(0.60)	1.10	(2.20)	79
		4	X (Option 2)	X	0.10	(0.20)	1.30	(2.60)	93
		4a	X (Option 3)	X	0.10	(0.20)	1.30	(2.60)	93
			Prill Tower	Predryer, dryer and cooler					
L 1-3	Low Density Prilling	1 (ELOC)	0	0	2.80	(5.60)	-	-	0
		2	0	X	0.85	(1.70)	1.95	(3.90)	70
		3	X (Option 1)	X	0.40	(0.80)	2.40	(4.80)	86
		4	X (Option 2)	X	0.20	(0.40)	2.60)	(5.20)	93
			Granulator	Cooler					
G 1-3	Granulation	1 (ELOC)	0	0	0.95	(1.90)	-	-	0
		2	X	X	0.30	(0.60)	0.65	(1.30)	68

[a] Emission factors reflect total emissions, including bypass emissions when applicable.

[b] This option is for a reduced flow wetted fibrous filter scrubber, no reduction in emissions are credited. However, environmental impacts will be changed.

0 - Existing Level of Control

X - Optional Control

density plants. This is a 93 percent reduction beyond ELOC. Table 6-2 presents the total annual particulate reduction over existing control levels for each model plant and control alternative. Emission reductions range from 76 Mg/year (84 TPY) for Alternative 2 for Model Plant H-1 to 683 Mg/year (753 TPY) for Alternative 4 for Model Plant L-3.

6.1.2 Secondary Air Quality Impacts

Secondary air pollutants are generated as a result of applying the control equipment. For ammonium nitrate plants, no air pollutants are generated by the control equipment used to achieve various control levels. There is, however, an increase in offsite power plant emissions caused by the additional electrical demand of the control equipment and the steam demand required to utilize the recovered AN particulates from scrubber liquor. For illustration, it was assumed that both the electrical and steam energy demand would be met by a coal fired utility boiler. These energy requirements are discussed in Section 6.4. Pollutants associated with the power plant would be particulates, SO_2 and NO_x.

Table 6-3 presents the range of secondary air emissions for each type of model plant. These are presented as the expected increase in a coal burning power plant's emissions over power plant emissions based on the control equipment used to meet the existing levels of control. Furthermore, the emissions for the power plant would meet current New Source Performance Standards. For the least affected case, Alternative 3 for Model Plant H-1, a decrease in power plant particulate emissions of 0.008 g/kg (0.016 lb/ton) of AN produced would occur, because this alternative requires less energy than the existing control levels.[1] In the worst case, Alternative 4 for Model Plant L-1, power plant emissions would increase by 0.036 g/kg (0.072 lb/ton) of AN produced. The corresponding reduction in the low density plant's AN particulate emissions over ELOC from applying the alternative would be 2.6 g/kg (5.2 lb/ton) of AN produced. Therefore, the increase in power plant particulate emissions would be less than 1.4 percent of the reduction in emissions caused by Alternative 4.

TABLE 6-2. TOTAL ANNUAL REDUCTION OVER EXISTING LEVEL OF CONTROL OF PARTICULATE EMISSIONS FOR CONTROL ALTERNATIVES
Mg/Year (Tons/Year)

Model Plant Number	Model Plant	Plant Capacity Mg/Day	Plant Capacity (TPD)	Control Alternative 1	Control Alternative 2	Control Alternative 3	Control Alternative 4	Control Alternative 4a
H-1	High Density Prilling	363	(400)	-	76 (84)	129 (142)	152 (167)	152 (167)
H-2		726	(800)	-	152 (167)	258 (284)	305 (335)	305 (335)
H-3		1089	(1200)	-	228 (251)	387 (426)	456 (502)	456 (502)
L-1	Low Density Prilling	181	(200)	-	114 (126)	140 (155)	152 (167)	
L-2		363	(400)	-	228 (251)	281 (309)	304 (335)	
L-3		816	(900)	-	512 (565)	631 (696)	683 (753)	
G-1	Granulator	363	(400)	-	76 (84)			
G-2		726	(800)	-	152 (167)			
G-3		1089	(1200)	-	228 (251)			

TABLE 6-3. SECONDARY AIR IMPACTS OVER ELOC FOR EACH MODEL PLANT AND CONTROL ALTERNATIVE[1]

Model Plant	Control Alternative	Power Plant Particulate Emissions Over ELOC 10^{-2} g/kg	Power Plant Particulate Emissions Over ELOC 10^{-2} lb/ton	AN Particulate Emissions Reduction From ELOC g/kg	AN Particulate Emissions Reduction From ELOC lb/ton	Percent Impact of Secondary Emissions Over AN Emissions Reduction	Power Plant SO_2 Emissions Over ELOC g/kg	Power Plant SO_2 Emissions Over ELOC lb/ton	Power Plant NO_x Emissions Over ELOC g/kg	Power Plant NO_x Emissions Over ELOC lb/ton
H-1	2	0.45	0.91	0.65	1.3	0.7	0.02	0.04	0.02	0.04
	3^a	-0.80	-1.60	1.1	2.2	-0.7	-0.03	-0.07	-0.03	-0.07
	4	1.11	2.22	1.3	2.6	0.8	0.05	0.10	0.04	0.09
	4a^a	-0.65	-1.30	1.3	2.6	-0.5	-0.03	-0.06	-0.02	-0.05
H-2	2	0.33	0.67	0.65	1.3	0.5	0.01	0.03	0.01	0.03
	3^a	-0.68	-1.36	1.1	2.2	-0.6	-0.03	-0.06	-0.03	-0.06
	4	1.14	2.29	1.3	2.6	0.9	0.05	0.10	0.04	0.09
	4a^a	-0.49	-0.98	1.3	2.6	-0.4	-0.02	-0.04	-0.02	-0.04
H-3	2	0.39	0.78	0.65	1.3	0.6	0.01	0.03	0.01	0.03
	3^a	-0.67	-1.34	1.1	2.2	-0.6	-0.03	-0.06	-0.03	-0.06
	4	1.20	2.40	1.3	2.6	0.9	0.05	0.10	0.05	0.10
	4a^a	-0.50	-1.00	1.3	2.6	-0.4	-0.02	-0.04	-0.02	-0.04
L-1	2	1.07	2.15	1.95	3.9	0.5	0.04	0.09	0.04	0.09
	3	1.68	3.37	2.4	4.8	0.7	0.07	0.15	0.07	0.14
	4	3.59	7.18	2.6	5.2	1.4	0.15	0.31	0.14	0.29
L-2	2	1.06	2.12	1.95	3.9	0.5	0.04	0.09	0.04	0.09
	3	1.66	3.33	2.4	4.8	0.7	0.07	0.14	0.07	0.14
	4	3.57	7.14	2.6	5.2	1.4	0.15	0.31	0.14	0.29
L-3	2	1.06	2.13	1.95	3.9	0.5	0.04	0.09	0.04	0.09
	3	1.70	3.41	2.4	4.8	0.7	0.07	0.15	0.07	0.14
	4	3.50	7.01	2.6	5.2	1.3	0.15	0.31	0.14	0.29
G-1	2	0.35	0.70	0.65	1.3	0.5	0.01	0.03	0.01	0.03
G-2	2	0.35	0.70	0.65	1.3	0.5	0.01	0.03	0.01	0.03
G-3	2	0.35	0.70	0.65	1.3	0.5	0.01	0.03	0.01	0.03

[a] The power plant emissions (secondary emissions) are less than the ELOC for this alternative because the control equipment for this alternative requires less energy than the control equipment for the ELOC.

Table 6-3 also presents the increases in SO_2 and NO_x power plant emissions for each type of model plant. Alternative 4 for Model Plant L-1 causes the largest increase in these emissions. In this case, the power plant would generate an increase in SO_2 and NO_x emissions of 0.150 g/kg (0.313 lb/ton) and 0.145 g/kg (0.291 lb/ton) of AN produced, respectively. The assumptions and calculations used in developing these air quality impacts can be found in Reference 1.

6.1.3 Summary of Air Quality Impacts

The primary air pollutant emissions from affected facilities in the AN industry are AN particulates. The major benefit of implementing the control alternatives is a reduction of particulate emissions, and thus a potential lessening of health and environmental hazards. The largest reduction in AN particulate emissions which would result from applying the control alternatives would be 683 Mg/year (753 TPY) for Alternative 4 of Model Plant L-3. The corresponding increase in power plant emissions would be 9.20 Mg/year (10.14 TPY), which is only a 1.3 percent impact on the particulate emission reduction. Therefore, the potential secondary air emissions are not considered significant.

6.2 WATER POLLUTION IMPACT

There would be no adverse water pollution impact due to the implementation of the proposed control alternatives. Water used in the wet scrubbers to control particulate emissions is usually recycled to the solution concentration process for complete recovery of the ammonium nitrate.

6.3 SOLID WASTE IMPACT

There would be no solid waste impact due to the application of the control alternatives, since the collected AN emissions are dissolved in the scrubber liquor and recycled to solution formation.

6.4 ENERGY IMPACT

The energy impact of the control alternatives is less than seven percent of the energy needed for the process equipment. The process equipment energy includes energy needs from solution formation through the finishing of the final product.[2]

The control of emissions involves the use of both electricity and steam. Electricity is used to power the pumps and fans associated with the control devices while steam is required to concentrate the weak scrubber liquor when it is recycled to the process.

The energy requirements for each model plant and control alternative are presented in Table 6-4. The incremental energy consumption over the energy required to meet existing level of control (ELOC) in addition to its percentage of the total plant energy demand is shown for each alternative. In the cases where a negative energy requirement over ELOC occurs, the control alternative requires less energy for operation than the control equipment used to meet the ELOC. Energy requirements over ELOC for the control equipment range from -11.72 TJ/yr (-11.11 x 10^9 Btu/yr) to 46.04 TJ/yr (43.64 x 10^9 Btu/yr). The effect on total plant energy demand associated with the control alternatives over ELOC ranges from -0.8 percent for Alternative 3 for Model Plant H-1 to 3.7 percent for Alternative 4 for Model Plant L-1.

6.5 OTHER IMPACTS

There would be no significant noise impact due to implementation of the regulatory alternatives. The increase in noise caused by the addition of fans for the control equipment would be small compared to the noise already generated by process equipment.

TABLE 6-4. ENERGY REQUIREMENT FOR MODEL PLANTS AND CONTROL ALTERNATIVES

Model Plant	Control Alternative	Control Equipment Energy		Energy Requirements Over ELOC		Total Plant Energy[a]		Energy Requirement Over ELOC as Percent of Total Plant Energy
		10^9 Btu/yr	TJ/yr	10^9 Btu/yr	TJ/yr	10^9 Btu/yr	TJ/yr	
H-1	1	16.66	17.58	-	-	544	574	-
	2	19.18	20.23	2.52	2.66	544	574	0.5
	3	12.21	12.88	-4.45	-4.69	544	574	-0.8
	4	22.80	24.05	6.14	6.48	544	574	1.1
	4a	13.08	13.80	-3.58	-3.78	544	574	-0.7
H-2	1	32.22	33.99	-	-	1086	1146	-
	2	35.94	37.92	3.72	3.93	1086	1146	0.3
	3	24.69	26.05	-7.53	-7.94	1086	1146	-0.7
	4	44.90	47.37	12.68	13.38	1086	1146	1.2
	4a	26.76	28.23	-5.46	-5.76	1086	1146	-0.5
H-3	1	47.20	49.80	-	-	1630	1720	-
	2	53.68	56.63	6.48	6.83	1630	1720	0.4
	3	36.09	38.07	-11.11	-11.72	1630	1720	-0.7
	4	67.11	70.80	19.91	21.00	1630	1720	1.2
	4a	38.88	41.02	-8.32	-8.78	1630	1720	-0.5
L-1	1	7.30	7.70	-	-	271	286	-
	2	10.28	10.85	2.98	3.14	271	286	1.1
	3	11.96	12.62	4.66	4.91	271	286	1.7
	4	17.22	18.17	9.92	10.46	271	286	3.7
L-2	1	14.50	15.30	-	-	544	574	-
	2	20.37	21.50	5.87	6.20	544	574	1.1
	3	23.71	25.01	9.21	9.71	544	574	1.7
	4	34.26	36.14	19.76	20.85	544	574	3.6
L-3	1	32.69	34.48	-	-	1223	1290	-
	2	45.93	48.45	13.24	13.97	1223	1290	1.1
	3	53.92	56.89	21.24	22.41	1223	1290	1.7
	4	76.33	80.52	43.64	46.04	1223	1290	3.6
G-1[b]	1	4.73	4.99	-	-	578	610	-
	2	6.68	7.05	1.95	2.06	578	610	0.3
G-2[b]	1	9.46	9.98	-	-	1153	1216	-
	2	13.35	14.08	3.89	4.10	1153	1216	0.3
G-3[b]	1	14.19	14.97	-	-	1731	1826	-
	2	20.03	21.13	5.84	6.16	1731	1826	0.3

[a] Includes energy needed for solution formation through finishing of the final product.

[b] The control equipment for the granulator is considered in the plant energy requirements, not in the control equipment energy requirements.

6.6 REFERENCES

1. Memo from Bowen, M. L., Radian Corporation, to file. September 1980. 4 p. Summary of secondary air pollution impact calculations.

2. Faith, W. L., Keyes and Clark. Industrial Chemicals. New York, John Wiley and Sons. 1975. 97-99.

7.0 COST ANALYSIS

A cost analysis of the control alternatives described in Chapter 5 is presented in this chapter. This chapter is divided into two major sections. Section 7.1 presents the costs associated with various control alternatives, including an analysis of capital and annualized costs. Both new facilities and existing facilities are considered. Other costs that may result from the application of control equipment are considered in Section 7.2, including costs imposed by water pollution control regulations and solid waste disposal requirements.

7.1 COST ANALYSIS OF CONTROL ALTERNATIVES

7.1.1 Introduction

The costs of implementing the control alternatives to control emissions from the solid ammonium nitrate industry are presented in this section. The cost analysis is based upon the model ammonium nitrate plants and the control alternatives presented in Chapter 5. The nine model plants, and the sources being controlled, are shown in Table 7-1. Emission factors for each source are presented in Table 7-2, and the control alternatives for each plant are presented in Table 7-3.

The cost of purchasing, installing and operating various control devices are presented in the following sections. The purchase costs for the control equipment (wetted fibrous filter scrubbers[1,2], entrainment scrubbers[3], two-tray scrubbers[4,5], and tray scrubbers[6]) were obtained from vendor quotes. Cost estimating manuals and published reports were used to determine costs for auxiliary equipment, (fans[7], pumps[8], motors[9], starters[9], downcomers[10], and stacks[11]). Equipment costs were scaled up to first quarter 1980 dollars using the Marshall and Stevens[12] index for the chemicals industry.

Total capital cost for installation of the various control devices was determined by applying component factors to the basic equipment

TABLE 7-1. MODEL AMMONIUM NITRATE PLANTS FOR COST ESTIMATES

Model Plant #	Process	Capacity Mg/Day (TPD)	Emission Sources
H-1	High Density Prilling	363 (400)	Prill Tower, Rotary Drum Cooler
H-2	High Density Prilling	726 (800)	Prill Tower, Rotary Drum Cooler
H-3	High Density Prilling	1089 (1200)	Prill Tower, Rotary Drum Cooler
L-1	Low Density Prilling	181 (200)	Prill Tower; Rotary Drum Predryer, Dryer, and Cooler
L-2	Low Density Prilling	363 (400)	Prill Tower, Rotary Drum Predryer, Dryer, and Cooler
L-3	Low Density Prilling	816 (900)	Prill Tower; Rotary Drum Predryer, Dryer, and Cooler
G-1	Granulation	363 (400)	Rotary Drum Granulator, Rotary Drum Cooler
G-2	Granulation	726 (800)	Rotary Drum Granulator, Rotary Drum Cooler
G-3	Granulation	1089 (1200)	Rotary Drum Granulator, Rotary Drum Cooler

TABLE 7-2. EMISSION FACTORS

	Uncontrolled		Existing Control	Existing		Control Option Equipment	Controlled	
	kg/Mg	(lbs/ton)		kg/Mg	(lbs/ton)		kg/Mg	(lbs/ton)
Solids Formation								
Low Density Prill Towers	0.7	(1.4)	None	0.7	(1.4)	Option 1 Collection Hood/WFFS^{a} 3.5 kPa (14" W.G.) ΔP	0.25	(0.5)
						Option 2 WFFS^{a} 3.5 kPa (14" W.G.) ΔP	0.05	(0.1)
High Density Prill Towers	1.55	(3.1)	Two-Tray Scrubber 2.75 kPa (11" W.G.) ΔP	0.7	(1.4)	Option 1^{5} Collection Hood/WFFS^{a} 3.5 kPa (14" W.G.) ΔP	0.25	(0.5)
						Option 2 and 3^{5} WFFS^{a} 3.5 kPa (14" W.G.) ΔP	0.05	(0.1)
Granulators	145	(290)	Entrainment Scrubber 3.5 kPa (14" W.G.) ΔP	0.25	(0.5)	Same	0.25	(0.5)
Solids Finishing								
Predryers, Dryer, Cooler	5.4*	(10.8)*	Tray Scrubber .75 kPa (3" W.G.) ΔP	0.7	(1.4)	Entrainment Scrubber 3.25 kPa (13" W.G.) ΔP	0.05	(0.1)

[a] Wetted Fibrous Filter Scrubber
*Average of EPA test data

TABLE 7-3. CONTROL ALTERNATIVES FOR MODEL AMMONIUM NITRATE PLANTS

Model Plant # - Alternative #	Process	Capacity Mg/Day (TPD)	Type of Control Device on Facilities	
			Prill Tower or Granulator	Predryer, Dryer or Cooler
H1-1	High Density Prilling	363 (400)	Tray Scrubber	Tray Scrubber
H1-2	High Density Prilling	363 (400)	Tray Scrubber	Entrainment Scrubber
H1-3	High Density Prilling	363 (400)	Collection Hood/WFFS[a] (Op.1)	Entrainment Scrubber
H1-4	High Density Prilling	363 (400)	Full Flow WFFS[a] (Op.2)	Entrainment Scrubber
H1-4a	High Density Prilling	363 (400)	Reduced Flow WFFS[a] (Op.3)	Entrainment Scrubber
H2-1 through H2-4a	High Density Prilling	726 (800)	Same controls as used on Alternatives H1-1 through H1-4a.	
H3-1 through H3-4a	High Density Prilling	1089 (1200)	Same controls as used on Alternatives H1-1 through H1-4a.	
L1-1	Low Density Prilling	181 (200)	None	Tray Scrubber
L1-2	Low Density Prilling	181 (200)	None	Entrainment Scrubber
L1-3	Low Density Prilling	181 (200)	Collection Hood/WFFS[a] (Op.1)	Entrainment Scrubber
L1-4	Low Density Prilling	181 (200)	Full Flow WFFS[a] (Op.2)	Entrainment Scrubber
L2-1 through L2-4	Low Density Prilling	363 (400)	Same controls as used on Alternatives L1-1 through L1-4.	
L3-1 through L3-4	Low Density Prilling	816 (900)	Same controls as used on Alternatives L1-1 through L1-4.	
G1-1	Granulation	363 (400)	Entrainment Scrubber	Tray Scrubber
G1-2	Granulation	363 (400)	Entrainment Scrubber	Entrainment Scrubber
G1-1 and G2-2	Granulation	726 (800)	Same controls as used on Alternatives G1-1 and G1-2.	
G3-1 and G3-2	Granulation	1089 (1200)	Same controls as used on Alternatives G1-1 and G1-2.	

[a] Wetted Fibrous Filter Scrubber

costs. These component factors, obtained from a cost estimating manual, take into account direct costs (ductwork, piping, electrical, instrumentation, structural costs, construction labor, etc.), indirect costs (engineering, contractor's fee, taxes, etc.), and contingencies.[13]

The annual cost of operating and maintaining the control devices includes direct operating expenses (utilities, labor[14], maintenance[15]) and capital charges. Capital charges include insurance[15], administrative overhead[15], taxes[16], and capital recovery (the annual cost for the payoff of the control devices).[15] Any net savings obtained from the application of the control equipment is subtracted from the annual operating costs to obtain the net annual cost of the control alternatives. Net savings is obtained from the ammonium nitrate recovered by the control equipment.

The net annual cost is divided by the quantity of pollutant removed by the control alternatives to determine the cost effectiveness of the control alternatives. Cost effectiveness is used as a means of comparing various alternatives.

The costs associated with controlling emissions from new facilities are discussed in Section 7.1.2. Cost considerations for existing facilities are discussed in Section 7.1.3.

7.1.2 New Facilities

Capital and annualized costs of applying the control alternatives to new ammonium nitrate solids production and finishing facilities are presented in this section. The costs associated with the control alternatives are presented in six subsections. Section 7.1.2.1 presents important considerations used in the determination of control equipment costs. Section 7.1.2.2 discusses the capital costs, and Section 7.1.2.3 presents the annual costs of the control alternatives. The effect of the control alternatives on ammonium nitrate product cost is described in Section 7.1.2.4. Section 7.1.2.5, cost effectiveness, compares the annual costs of the control options to existing cases. The base cost of an ammonium nitrate plant is discussed in Section 7.1.2.6.

A 363 Mg/day (400 TPD) plant is used to compare equipment requirements and costs, because all three types of plants have a model plant of this size.

7.1.2.1 Basis for Equipment Costs. This section presents important points which were considered in determining the costs of the control equipment. All the equipment, except for motors and starters, is made of stainless steel because of the corrosiveness of ammonium nitrate. Table 7-4 presents control equipment operating parameters which were obtained from vendors and are typical of industrial operation. The control devices and auxiliary equipment were sized to handle the airflows and emissions specified for the model plants in Tables 5-7 through 5-9. An example of the equipment needed to control emissions from the sources in 363 Mg/day (400 TPD) model plants are presented in Tables 7-5a through 7-5d. Figures 7-1 and 7-2 are included to clarify the location of the control equipment, stacks, fans and ductwork for the prilling towers. These figures are representative and do not show exact placement of the equipment.

Wet scrubbers are used to control emissions from both solids formation facilities, granulators and prill towers, and from solids finishing facilities, predryers, dryers and coolers. The purchase cost of the control equipment includes the cost of a scrubber (wetted fibrous filter[1,2], entrainment[3], two-tray[4,5], tray[6]), fan[7], recirculating pump[8], the associated motors[9] and starters[9], downcomers[10] and stacks.[11]

State regulations require that new plants must be testable, which means a stack on the discharge. Therefore, even in cases where no control is required, like the low density prill tower, fan and stack costs were determined.

Various techniques are used for applying the selected control equipment to the different sized model prilling and granulation plants. For prilling operations and their solids finishing equipment, the facilities are sized for a capacity equivalent to the overall plant production capacity. Granulation facilities, on the other hand, are usually one specific size. Production capacity for the granulation plant is met

TABLE 7-4. CONTROL EQUIPMENT SPECIFICATIONS

Two-Tray Scrubber (for prill towers)

Pressure Drop: 2.75 kPa (11 in H_2O)[5]
Liquid to Gas Ratio: 0.47 m^3 liq./1000 acm gas (3.5 gpm/1000 acfm)[4]
Construction Material: 316 SS
Fan Location: At scrubber exhaust
Scrubber liquor is returned to process

Tray Scrubber (for predryers, dryers, and coolers)

Pressure Drop: .75 kPa (3.0 in H_2O)[6]
Liquid to Gas Ratio: 0.4 m^3 liq./1000 acm gas (3 gpm/1000 acfm)[6]
Construction Material: 304 SS
Fan Location: At scrubber exhaust
Scrubber Liquor is returned to process
Inlet Velocity: 15.2 m/s (3000 fpm)[3]

Entrainment Scrubber (for predryers, dryers, coolers, granulators)

Pressure Drop: 3.2 kPa (13 in H_2O)[3], 3.5 kPa (14 in H_2O) for granulators
Liquid to Gas Ratio: .87 m^3 liq./1000 acm gas (6.5 gpm/1000 acfm)[3]
Construction Material: 304 SS
Fan Location: At scrubber exhaust
Scrubber Liquor is returned to process

Wetted Fibrous Filter Scrubber (for prill towers)

Pressure Drop: 3.5 kPa (14.0 in H_2O)[2]
Liquid to Gas Ratio: .47 m^3 liq./1000 acm gas (3.5 gpm/1000 acfm)
Air Velocity: .13 m/s (25 ft/min) through high energy elements
Wetted fibrous filter scrubber used in conjunction with a dust collection hood controls 20 percent of total tower airflow
Construction Material: Glass fiber filter elements, 304 SS for shell and dust collection hood
Fan Location: At scrubber exhaust
Scrubber liquor is returned to process

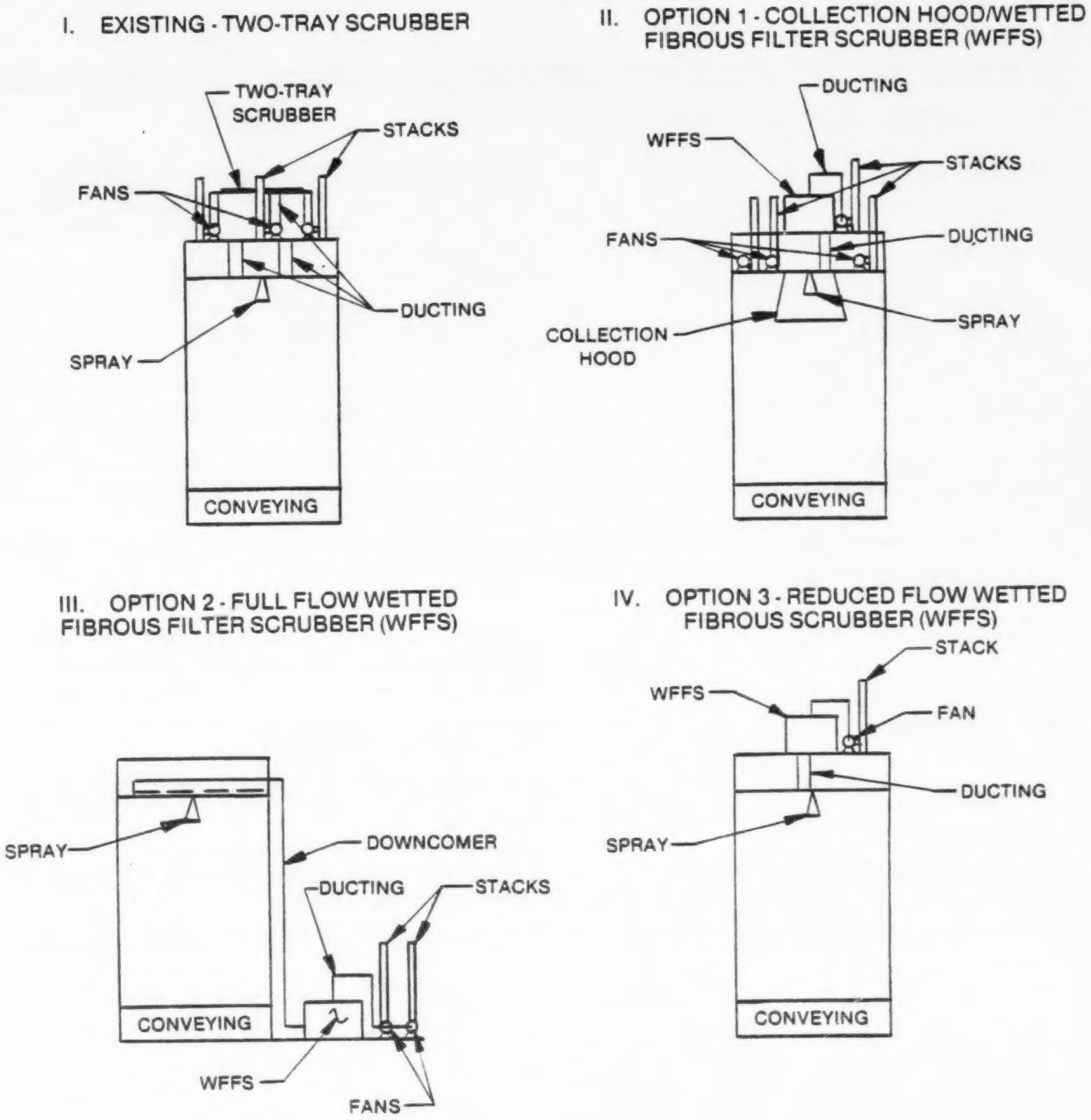
TABLE 7-5a. MAJOR EQUIPMENT REQUIREMENTS FOR CONTROL OF HIGH DENSITY PRILL TOWERS 363 Mg/Day (400 TPD) FACILITY

I. EXISTING LEVEL OF CONTROL	
Control Device	Two-Tray Scrubber, Airflow through device: 83 acms (176,000 acfm)
Fans and Motors	3 @ 24 scms (51,700 scfm) @ 311 K (100°F), 1200 rpm, 104 kw (140 bhp)
Stacks	3 @ 1.5 m (5 ft.) diameter, 7 m (23 ft.) high, SS
Recirculation Pump and Motor	2.4 m^3/min (620 GPM) 299 kPa (100 ft. of water) 30 kw (40 bhp)
II. CONTROL OPTION I	
Control Device	Collection Hood/Wetted Fibrous Filter Scrubber, Airflow through device: 17 acms (35,200 acfm)
Fan and Motor	15 scms (31,000 scfm) @ 311 K (100°F), 1800 rpm, 75 kw (100 bhp)
Stack	1.2 m (4.0 ft.) diameter, 12 m (40 ft.) high, SS-stack from scrubber
Recirculation Pump and Motor	.47 m^3/min (125 GPM), 299 kPa (100 ft. of water) 6.0 kw (8 bhp)
Bypass Fans	3 @ 20 scms (41,300 scfm) @ 311 K (100°F), 600 rpm, 3.7 kw (5 bhp)
Bypass Stacks	3 @ 1.4 m (4.5 ft.) diameter, 9.5 m (31 ft.) high,SS

TABLE 7-5a (cont.)

MAJOR EQUIPMENT REQUIREMENTS FOR CONTROL OF HIGH DENSITY PRILL TOWERS

III. CONTROL OPTION 2	
Control Device	Wetted Fibrous Filter Scrubber, Airflow through device: 83 acms (176,000 acfm)
Downcomer	304 SS ductwork, 2.7 m (9 ft.) diameter, 76 m (250 ft.) length
Fans and Motors	2 @ 37 SCMS (77,500 scfm) @ 311 K (100°F), 1200 rpm, 201 kw (270 bhp)
Stacks	2 @ 1.8 m (6 ft.) diameter, 18 m (60 ft.) high, SS
Recirculation Pump and Motor	2.4 m^3/min (620 gpm), 299 kPa (100 ft. of water) 30 kw (40 bhp)
IV. CONTROL OPTION 3	
Control Device	Wetted Fibrous Filter Scrubber, Airflow through device: 21 acms (45,400 acfm)
Fan and Motor	18.4 scms (39,000 scfm) @ 311 K (100°F), 1800 rpm, 97 kw (130 bhp)
Stack	1.4 m (4.5 ft.) diameter, 13 m (42 ft.) high, SS
Recirculation Pump and Motor	0.6 m^3/min (160 gpm), 299 kPa (100 ft. of water) 7.5 kw (10 bhp)



I. EXISTING - TWO-TRAY SCRUBBER

II. OPTION 1 - COLLECTION HOOD/WETTED FIBROUS FILTER SCRUBBER (WFFS)

III. OPTION 2 - FULL FLOW WETTED FIBROUS FILTER SCRUBBER (WFFS)

IV. OPTION 3 - REDUCED FLOW WETTED FIBROUS SCRUBBER (WFFS)

TWO-TRAY SCRUBBER
STACKS
FANS
DUCTING
SPRAY
CONVEYING
DUCTING
WFFS
STACKS
FANS
DUCTING
SPRAY
COLLECTION HOOD
CONVEYING
SPRAY
DOWNCOMER
DUCTING
STACKS
CONVEYING
WFFS
FANS
STACK
WFFS
FAN
DUCTING
SPRAY
CONVEYING

Figure 7-1. Control equipment configuration for high density prill towers - 363 Mg/day (400 TPD).

TABLE 7-5b. MAJOR EQUIPMENT REQUIREMENTS FOR CONTROL OF LOW DENSITY PRILL TOWERS 363 Mg/Day (400 TPD) FACILITY

I. EXISTING LEVEL OF CONTROL	
Fans and Motors	3 @ 24 scms (50,700 scfm) @ 311 K (100°F) 600 rpm, 4.5 kw (6 bhp)
Stacks	3 @ 1.5 m (5 ft.) diameter, 10 m (33 ft.) high
II. CONTROL OPTION I	
Control Device	Collection Hood/Wetted Fibrous Filter Scrubber, Airflow through device: 16.5 acms (34,900 acfm)
Fan and Motor	14 scms (30,000 scfm) @ 311 K (100°F), 1800 rpm, 75 kw (100 bhp)
Stack	1.2 m (4.0 ft.) diameter, 12 m (40 ft.) high, SS-stack from scrubber
Recirculation Pump and Motor	.47 m^3min (125 gpm), 299 kPa (100 ft. of water), 6.0 kw (8 bhp)
Bypass Fans	3 @ 19 scms (40,700 scfm) @ 311 K (100°F), 600 rpm, 3.7 kw (5 bhp)
Bypass Stacks	3 @ 1.4 m (4.5 ft.) diameter, 9.5 m (31 ft.) high, SS
III. CONTROL OPTION 2	
Control Device	Wetted Fibrous Filter Scrubber, Airflow through device: 82 acms (173,000 acfm)
Downcomer	304 SS ductwork, 2.7 m (9 ft.) diameter, 76 m (250 ft.) length

TABLE 7-5b (cont.)

MAJOR EQUIPMENT REQUIREMENTS FOR CONTROL OF LOW DENSITY PRILL TOWERS

Fans and Motors	2 @ 36 scms (76,000 scfm) @ 311 K (100°F), 1200 rpm, 205 kw (275 bhp)
Stacks	2 @ 1.8 m (6 ft.) diameter, 18 m (60 ft.) high, SS
Recirculation Pump and Motor	2.4 m^3/min (620 gpm), 299 kPa (100 ft. of water), 30 kw (40 bhp)

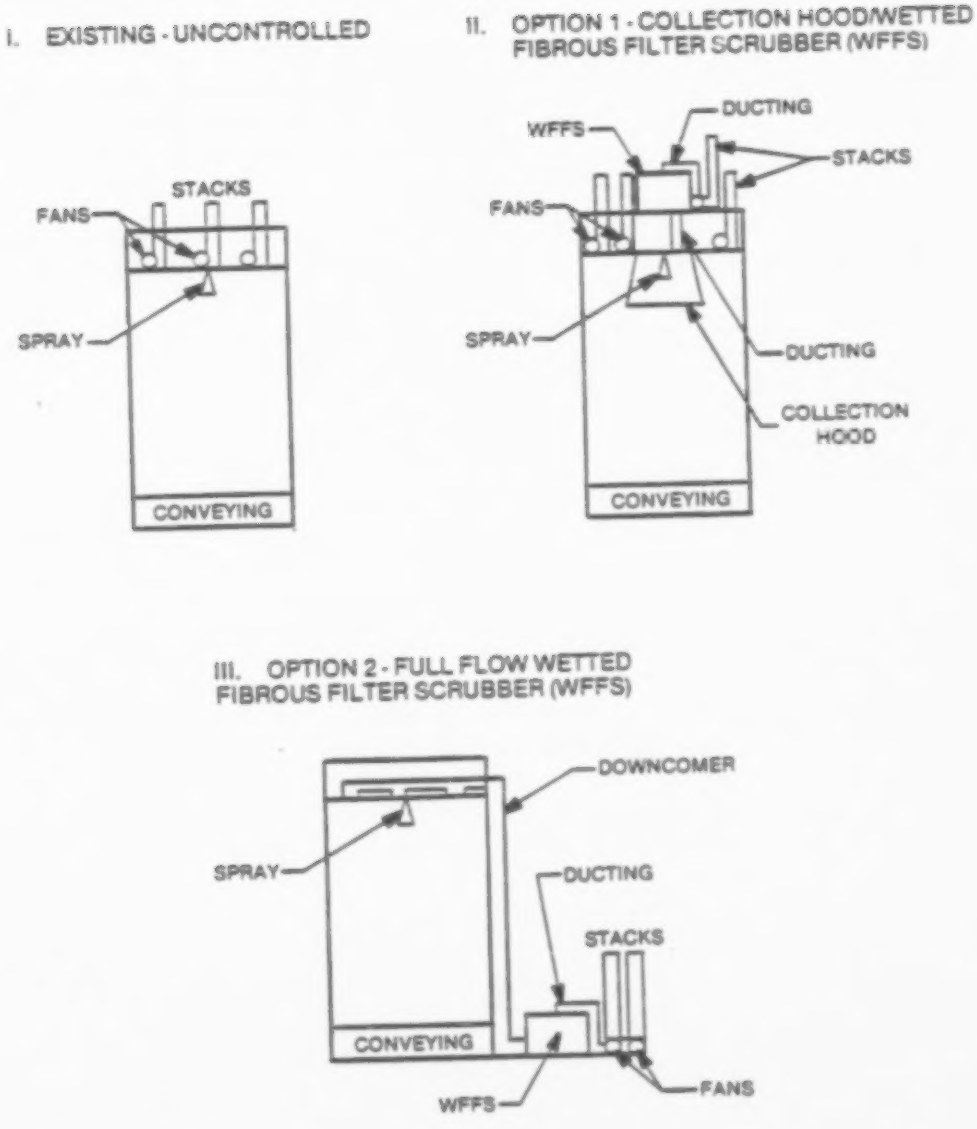

I. EXISTING - UNCONTROLLED
STACKS
FANS
SPRAY
CONVEYING
II. OPTION 1 - COLLECTION HOOD/WETTED FIBROUS FILTER SCRUBBER (WFFS)
DUCTING
WFFS
STACKS
FANS
SPRAY
DUCTING
COLLECTION HOOD
CONVEYING
III. OPTION 2 - FULL FLOW WETTED FIBROUS FILTER SCRUBBER (WFFS)
DOWNCOMER
SPRAY
DUCTING
STACKS
CONVEYING
WFFS
FANS

Figure 7-2. Control equipment configuration for low density prill towers - 363 Mg/day (400 TPD).

TABLE 7-5c. MAJOR EQUIPMENT REQUIREMENTS FOR CONTROL OF GRANULATORS 363 Mg/Day (400 TPD) FACILITY

Control Device	Entrainment Scrubber, Airflow through device: 22 acms (47,500 acfm)
Fan and Motor	18.9 scms (40,000 SCFM) @ 316 K (110°F), 1800 rpm, 112 kw (150 bhp)
Stack	1.8 m (6 ft.) diameter, 18 m (60 ft.) high, SS
Recirculation Pump and Motor	1.2 m^3/min (310 gpm), 299 kPa (100 ft. of water), 15 kw (20 bhp)

TABLE 7-5d. MAJOR EQUIPMENT REQUIREMENTS FOR CONTROL OF COOLERS, DRYERS, PREDRYERS 363 Mg/Day (400 TPD) FACILITY

I. EXISTING LEVEL OF CONTROL	
Control Device	Tray Scrubber, Airflow through device: 11 acms (24,000 acfm)
Fan and Motor	9.4 scms (20,000 scfm) @ 330 K (135°F), 900 rpm, 15 kw (20 bhp)
Stack	.91 (3.0 ft.) diameter, 9 m (30 ft.) high, SS
Recirculation Pump and Motor	.28 m^3/min (75 GPM), 299 kPa (100 ft. of water), 3.7 kw (5 bhp)
II. OPTION CONTROL	
Control Device	Entrainment Scrubber, Airflow through device: 11 acms (24,000 acfm)
Fan and Motor	9.4 scms (20,000 scfm) @ 330 K (135°F) 1800 rpm, 60 kw (80 bhp)
Stack	.91 m (3.0 ft.) diameter, 9 m (30 ft.) high, SS
Recirculation Pump and Motor	.60 m^3/min (160 GPM), 299 kPa (100 ft. of water), 6.7 kw (9 bhp)

by constructing multiple processing trains to reach the desired capacity. As discussed in Chapter 5, the model granulation plant has a capacity of 363 Mg/Day (400 TPD). To meet the other model plant capacities, 726 Mg/Day (800 TPD) and 1089 Mg/Day (1200 TPD), two and three 363 Mg/Day (400 TPD) processing trains were used.

Control equipment for prilling plants and their solids finishing equipment was sized for specific airflows associated with the model plants.[7] For the granulation plant, the control equipment was sized for airflows from the 363 Mg/Day (400 TPD) plant. For the other granulation plants, the control equipment was the same size and was added to the additional processing train. The equipment cost, therefore, was obtained by doubling or tripling the costs of the 363 Mg/Day (400 TPD) control equipment.

In addition, the prill tower control equipment location was varied depending on the control option used. For the full airflow case (Option 2 in both model plants), the wetted fibrous filter scrubber was too large to place on the top of the tower. Therefore, for Option 2 a downcomer was required to collect and discharge prill tower emissions to a ground level wetted fibrous filter scrubber. For all other options the control equipment was located on top of the tower, and the additional cost of constructing a prill tower capable of supporting the control equipment was estimated. These costs and procedures would not apply to existing prill towers.

7.1.2.2 Capital Costs. Capital costs represent the total investment required for purchase and installation of the basic control equipment and associated auxiliaries. Capital cost estimates for each control system were developed by applying cost component factors[13] to the equipment costs to obtain total capital costs (including indirect costs). Costs for research and development, and costs for possible production losses during equipment installation and start-up are not included. Costs are presented in first quarter 1980 dollars.

Total cost for the complete purchase and installation of the control equipment and auxiliaries was determined by applying the component factors outlined in Table 7-6 to the basic equipment costs. As an example, the capital costs associated with controlling emissions from individual sources (i.e. cooler, dryer, predryer, prill tower, and granulator) in the 363 Mg/day (400 TPD) model ammonium nitrate plants are presented in Table 7-7. This table provides the cost of the control devices alone, the costs for all major equipment, and the total installed capital costs to control the emission sources.

The costs of the control equipment[17] needed for each individual source were combined (Table 7-3) to give the total installed cost and total equipment cost for each control alternative. The capital costs of the control alternatives are presented in Table 7-8. Included in Table 7-8 are total equipment cost, including auxiliaries, total installed capital cost of the equipment, and a comparison of total installed cost for the alternatives relative to the existing level of control (Alternative 1). Also included in Table 7-8 are the emissions reductions achieved by the various control alternatives. This information is used to determine the recovery credit of the control alternatives.

Since the cost of scrubber systems is directly related to the airflow through the scrubber, some of the control options have lower or slightly higher capital costs than the ELOC. Alternative 4a for high density prill towers uses a reduced airflow; therefore, the control equipment costs less than the ELOC. In the case of Alternative 3 for both types of prilling operations, the scrubber only treats twenty percent of the airflow and the control equipment cost is only six percent greater than the costs of the ELOC. Presently, some plants in the AN industry use these control systems to control prill tower emissions.

7.1.2.3 Annualized Costs. Annualized costs represent the yearly cost of operating and maintaining the pollution control system. The basis for the annualized cost estimates is presented in Table 7-9. All annualized costs were based on 7728 hr/yr of operation.

TABLE 7-6. COMPONENT CAPITAL COST FACTORS[14] FOR WET SCRUBBERS AS A FUNCTION OF EQUIPMENT COST, Q

Component	Direct costs	
	Material	Labor
Equipment	1.00 Q	0.09 Q
Ductwork	0.08 Q	0.07 Q
Instrumentation	0.05 Q	0.02 Q
Electrical	0.06 Q	0.12 Q
Foundations	0.03 Q	0.05 Q
Structural	0.06 Q	0.03 Q
Sitework	0.02 Q	0.02 Q
Painting	0.005 Q	0.02 Q
Piping	0.09 Q	0.08 Q
Total direct costs	1.40 Q	0.50 Q

Component	Indirect costs	
	Measure of costs	Factor
Engineering	10 percent material and labor	0.19 Q
Contractor's fee	15 percent material and labor	0.29 Q
Shakedown	5 percent material and labor	0.10 Q
Spares	1 percent material	0.01 Q
Freight	3 percent material	0.04 Q
Taxes	3 percent material	0.04 Q
Total indirect costs		0.67 Q
Contingencies - 20 percent of direct and indirect costs		0.51 Q
Total capital costs		3.08 Q

TABLE 7-7. CAPITAL COST FOR THE CONTROL OF INDIVIDUAL SOURCES IN 363 Mg/Day (400 TPD) MODEL AMMONIUM NITRATE PLANTS

Plant Type	Source of Emissions	Control Equipment	Cost of Control[a] Device	Major Equipment Cost[b]	Total Installed[c] Cost
High Density Prilling	Cooler	ELOC* Tray Scrubber	24,000	60,000	184,000
	Cooler	Entrainment Scrubber	38,000	71,000	219,000
	Prill Tower	ELOC Two-Tray Scrubber	215,000	340,000	1,040,000
	Prill Tower	Collection Hood/WFFS[d] (Op.1)	124,000	352,000	1,090,000
	Prill Tower	Full Flow WFFS[d] (Op.2)	558,000	940,000	2,900,000
	Prill Tower	Reduced Flow WFFS[d] (Op.3)	158,000	249,000	767,000
Low Density Prilling	Predryer	ELOC Tray Scrubber	26,000	61,000	187,000
	Predryer	Entrainment Scrubber	38,000	71,000	217,000
	Dryer	ELOC Tray Scrubber	26,000	61,000	187,000
	Dryer	Entrainment Scrubber	38,000	71,000	217,000
	Cooler	ELOC Tray Scrubber	35,000	59,000	181,000
	Cooler	Entrainment Scrubber	37,000	69,000	210,000
	Prill Tower	ELOC - Uncontrolled	-	148,000	454,000
	Prill Tower	Collection Hood/WFFS[d] (Op.1)	124,000	350,000	1,080,000
	Prill Tower	Full Flow WFFS[d] (Op.2)	564,000	943,000	2,910,000
Granulation	Cooler	ELOC Tray Scrubber	26,000	63,000	192,000
	Cooler	Entrainment Scrubber	39,000	72,000	221,000
	Granulator	ELOC Entrainment Scrubber	57,000	122,000	374,000

[a] Includes only the control device cost.

[b] Includes cost of control device, fans, pumps, motors, starter, downcomers, and stacks.

[c] Based on the component capital cost factors for direct and indirect cost from Table 7-7.

[d] Wetted fibrous filter scrubber.

*ELOC = Existing Level of Control

TABLE 7-8. CAPITAL COSTS OF CONTROL ALTERNATIVES FOR MODEL PLANTS

Plant[a] No.	Reg.[b] Alt.	Case	Total[c] Equipment Cost	Total[d] Installed Cost	Difference in Total Installed Cost for Alternative Relative to ELOC* %	Emission Reductions[e] Achieved by Control Alternative		Emissions for Alternative Relative to ELOC* %
						Mg/yr	(ton/yr)	
H1	1	H1-1	400,000	1,230,000	-	649	715	-
	2	H1-2	411,000	1,270,000	3.3	725	799	12
	3	H1-3	423,000	1,300,000	5.7	776	856	20
	4	H1-4	1,010,000	3,110,000	153	801	883	24
	4a	H1-4a	320,000	986,000	-20	801	883	24
H2	1	H2-1	657,000	2,020,000	-	1,297	1,430	-
	2	H2-2	669,000	2,060,000	2.0	1,448	1,597	12
	3	H2-3	721,000	2,220,000	9.9	1,553	1,713	20
	4	H2-4	1,800,000	5,560,000	175	1,600	1,764	24
	4a	H2-4a	564,000	1,740,000	-14	1,600	1,764	24
H3	1	H3-1	896,000	2,760,000	-	1,945	2,144	-
	2	H3-2	900,000	2,770,000	0.4	2,173	2,396	12
	3	H3-3	1,050,000	3,230,000	17	2,330	2,569	20
	4	H3-4	2,680,000	8,140,000	195	2,400	2,647	24
	4a	H3-4a	794,000	2,450,000	-11	2,400	2,647	24
L1	1	L1-1	188,000	580,000	-	824	908	-
	2	L1-2	219,000	675,000	16	938	1,034	14
	3	L1-3	363,000	1,120,000	93	964	1,063	17
	4	L1-4	664,000	2,050,000	253	976	1,076	19
L2	1	L2-1	327,000	1,010,000	-	1,647	1,816	-
	2	L2-2	356,000	1,100,000	8.9	1,874	2,067	14
	3	L2-3	559,000	1,720,000	70	1,927	2,125	17
	4	L2-4	1,150,000	3,550,000	251	1,951	2,151	19
L3	1	L3-1	668,000	2,060,000	-	3,707	4,086	-
	2	L3-2	696,000	2,140,000	3.9	4,218	4,652	14
	3	L3-3	1,060,000	3,260,000	58	4,336	4,782	17
	4	L3-4	2,220,000	6,860,000	233	4,390	4,841	19
G1	1	G1-1	183,000	565,000	-	17,464	19,250	-
	2	G1-2	193,000	594,000	5.1	17,531	19,333	0.4
G2	1	G2-1	366,000	1,130,000	-	34,927	38,500	-
	2	G2-2	386,000	1,190,000	5.3	35,061	38,665	0.4
G3	1	G3-1	549,000	1,700,000	-	52,391	57,750	-
	2	G3-2	579,000	1,780,000	4.7	52,593	57,969	0.4

[a] Model Plants from Table 7-1.

[b] Control Alternatives from Table 7-3.

[c] Includes cost of control device, fans, pumps, motors, starters, downcomers and stacks.

[d] Based on the component capital cost factors for direct and indirect costs, Table 7-7.

[e] Based on the emission factors detailed in Table 7-2.

*ELOC = Existing Level of Control

TABLE 7-9. BASIS FOR SCRUBBER ANNUALIZED COST ESTIMATES (1980)

Direct Operating Costs	
Utilities	
Water	Condensate from solution formation processes assumed available free of charge[a]
Electricity	$.04/kwh
Operating Labor	$17.45/hr[14]
Operating Hours	
Process Equipment	7,728 hours/year
Scrubbers	7,728 hours/year
	Each scrubber requires one eighth of an operator while in operation[15]
Maintenance	5.5 percent of capital investment[15]
Capital Charges	
Capital Recovery Factor	13.15 percent of capital investment[b]
Taxes and Insurance	5.0 percent of capital investment[15,16]
Administrative Overhead	2.5 percent of capital investment[15]
Recovery Credit	$55/Mg ($50/ton)

[a] This condensate would contribute to a plant's water pollution loading, if not used by scrubbers. Since costs of treatment and disposal are avoided, the assumption that it is available free of charge is conservative.

[b] Based on a 15-year equipment life[15] and a 10 percent interest rate.

Electricity costs were based on the power required to run the electric motors used to operate fans and pumps. A 60 percent efficiency was assumed for pumps. Brake horsepower for the motors was determined by using power curves from cost estimating manuals;[18] motor efficiency of 90 percent was assumed to provide the total power requirement. The annual cost of electricity was based upon an electricity cost of $.04/kwh.

Annual labor cost for the operation of the control equipment is the product of the total labor rate[14] ($17.45/hr), the operating hours per year of the control process (7728 hr/yr), and the number of operators required to run the control equipment[15] (1/8 operator/unit). The annual labor cost to operate a single control device is estimated to be $16,860/yr.

The ammonium nitrate recovered by the various control devices was estimated to have a net credit of $55/Mg AN ($50/ton AN) recovered,[19] based on current industry practice.[20] Typically, scrubber liquor is maintained at a concentration of 15 percent AN. A purge stream is drawn off to maintain this 15 percent AN concentration. Usually, this purge liquor is used to redissolve off-size/off-specification AN prills and granules, which produces a liquor of 30 to 60 percent AN. This solution is commonly sent to a surge tank, where it is mixed with the 83 percent AN solution produced in the neutralizer. It is then concentrated in the evaporator process, and sent to the solids forming process equipment. The cost of recovering ammonium nitrate was based on concentrating a 30 percent AN solution to 99.4 percent. The recovery credit was determined by taking the difference of the cost of concentrating the ammonium nitrate and the present sale price of $100/Mg ($91/ton).[21] The amount of ammonium nitrate recovered annually by the control alternatives, presented in Table 7-8, was used to determine the annual recovery credit.

The annualized cost for the control of individual sources (i.e., cooler, dryer, predryer, prill tower, and granulator) in the 363 Mg/day (400 TPD) model plants is presented in Table 7-10. This table presents the annual cost for electricity to operate the control device, and the

TABLE 7-10. ANNUALIZED COST FOR THE CONTROL OF INDIVIDUAL SOURCES IN 363 Mg/Day (400 TPD) MODEL AMMONIUM NITRATE PLANTS

Plant Type	Source of Emissions	Control Equipment	Electricity[a] Cost	Total Annual[b] Cost	Net Annual Cost[c] After Recovery Credits
High Density Prilling	Cooler	ELOC* Tray Scrubber	6,200	72,000	41,000
	Cooler	Entrainment Scrubber	22,600	97,000	63,000
	Prill Tower	ELOC Two-Tray Scrubber	118,000	405,000	400,000
	Prill Tower	Collection Hood/WFFS[e] (Op.1)	30,800	331,000	323,000
	Prill Tower	Full Flow WFFS[e] (Op.2)	150,000	924,000	914,000
	Prill Tower	Reduced Flow WFFS[e] (Op.3)	35,900	254,000	244,000
Low Density Prilling	Predyer	ELOC Tray Scrubber	5,700	72,000	41,000
	Predryer	Entrainment Scrubber	21,800	96,000	62,000
	Dryer	ELOC Tray Scrubber	5,700	72,000	41,000
	Dryer	Entrainment Scrubber	21,800	96,000	62,000
	Cooler	ELOC Tray Scrubber	5,700	70,000	40,000
	Cooler	Entrainment Scrubber	21,000	93,000	59,000
	Prill Tower	ELOC - Uncontrolled	4,400	123,000	123,000
	Prill Tower	Collection Hood/WFFS[e] (Op.1)	32,000	331,000	329,000
	Prill Tower	Full Flow WFFS[e] (Op.2)	151,000	927,000	923,000
Granulation	Cooler	ELOC Tray Scrubber	5,900	73,000	43,000
	Cooler	Entrainment Scrubber	22,000	97,000	63,000
	Granulator	ELOC Entrainment Scrubber	43,500	158,000	-775,000[d]

[a] Based on 7728 hr/yr operation at $.04/kwh.

[b] Includes electricity, labor, capital charge, taxes, insurance and maintenance based on Table 7-9

[c] The cost after applying a recovery credit of $55/Mg AN ($50/ton AN).

[d] Negative indicates credit is greater than cost.

[e] Wetted fibrous filter scrubber.

*ELOC = Existing Level of Control

annualized cost of the control device before and after consideration of recovery credits. The net annual cost of the control devices, including recovery credits, ranges from $40,000 for existing control of emissions from a cooler, to $923,000 for the full flow wetted fibrous filter scrubber used to control emissions from prill towers. The negative annual cost for the granulator scrubber, -$775,000, indicates that the recovery credit is greater than the operating costs.

The annual costs of controlling individual sources, as shown in Table 7-10, were combined to determine the annual costs of the control alternatives. These annual costs are presented in Table 7-11; the annual costs of the control alternatives with and without recovery credits are presented.

7.1.2.4 Effect of Control Alternatives on Product Cost. The impact of the control alternatives on the price of the product was also determined and is presented in Table 7-11. This cost impact indicates the cost per unit of ammonium nitrate produced. It is calculated by dividing the net annual cost of the control alternative by the annual model plant production.

Based upon a product selling cost of $91/ton, the percentage impacts on product cost could range from 2 to 8 percent for high density plants and 2 to 11 percent for low density plants. For granulation plants the impact would be negative, since the value of the recovered product exceeds control equipment costs.

7.1.2.5 Cost Effectiveness. Cost effectiveness, presented in Table 7-11, is used as a means of comparing control alternatives. It is defined as the total annualized cost of the pollution control system, divided by the quantity of pollutant removed by the system. The cost effectiveness of the control alternatives can be compared directly to the existing level of control by using the following equation.

$$\text{Cost Effectiveness} = \frac{C_x - C_E}{P_x - P_E}$$

TABLE 7-11. ANNUALIZED COST AND COST EFFECTIVENESS OF CONTROL ALTERNATIVES FOR MODEL AMMONIUM NITRATE FACILITIES

Plant[a] No.	Reg.[b] Alt.	Case	Net Annual Cost[c] $/yr		Effect on Cost[e] of Product (including recovery credit)		Cost[f] Effectiveness (including recovery credit)		Cost Effectiveness Relative to ELOC* (including recovery credit)	
			Without Recovery Credit	With Recovery Credit[d]	$/Mg	$/ton	$/Mg	$/ton	$/Mg	$/ton
H1	1	H1-1	476,000	440,000	3.77	3.42	679	616	-	-
	2	H1-2	502,000	462,000	3.84	3.58	637	578	287	262
	3	H1-3	428,000	386,000	3.31	3.00	497	451	-422	-383
	4	H1-4	1,020,000	976,000	8.36	7.58	1224	1110	3516	3190
	4a	H1-4a	350,000	306,000	2.61	2.37	381	346	-880	-798
H2	1	H2-1	800,000	729,000	3.12	2.83	562	510	-	-
	2	H2-2	840,000	760,000	3.25	2.95	525	476	205	186
	3	H2-3	724,000	638,000	2.73	2.48	411	372	-355	-322
	4	H2-4	1,830,000	1,740,000	7.44	6.75	1087	986	3337	3027
	4a	H2-4a	612,000	525,000	2.25	2.04	327	297	-674	-611
H3	1	H3-1	1,110,000	1,010,000	2.87	2.60	517	469	-	-
	2	H3-2	1,160,000	1,040,000	2.97	2.69	478	434	131	119
	3	H3-3	1,030,000	903,000	2.58	2.34	387	351	-306	-278
	4	H3-4	2,660,000	2,530,000	7.22	6.55	1055	957	3331	3022
	4a	H3-4a	844,000	713,000	2.03	1.84	297	269	-605	-590
L1	1	L1-1	214,000	168,000	2.88	2.61	204	185	-	-
	2	L1-2	263,000	213,000	3.65	3.31	227	206	394	357
	3	L1-3	410,000	359,000	6.14	5.57	372	338	1358	1232
	4	L1-4	711,000	659,000	11.29	10.24	676	613	3222	2923
L2	1	L2-1	335,000	244,000	2.08	1.89	148	134	-	-
	2	L2-2	406,000	303,000	2.60	2.36	162	147	259	235
	3	L2-3	614.000	507,000	4.35	3.95	263	239	938	851
	4	L2-4	1,210,000	1,110,000	9.47	8.59	567	514	2849	2585
L3	1	L3-1	637,000	433,000	1.64	1.49	117	106	-	-
	2	L3-2	768,000	536,000	2.05	1.86	127	115	201	182
	3	L3-3	1,150,000	906,000	3.46	3.14	209	189	749	680
	4	L3-4	2,330,000	2,090,000	7.97	7.23	477	433	2420	2195
G1	1	G1-1	231,000	-732,000	-6.25	-5.67	-42	-38	-	-
	2	G1-2	254,000	-712,000	-6.10	-5.53	-41	-37	266	241
G2	1	G2-1	462,000	-1,460,000	-6.25	-5.67	-42	-38	-	-
	2	G2-2	508,000	-1,420,000	-6.10	-5.53	-41	-37	266	241
G3	1	G3-1	693,000	-2,200,000	-6.25	-5.67	-42	-38	-	-
	2	G3-2	762,000	-2,140,000	-6.10	-5.53	-41	-37	266	241

[a] Model Plants from Table 7-1.

[b] Control alternatives from Table 7-3.

[c] Based on annualized cost estimates outlined in Table 7-10.

[d] Using a credit of $55/Mg ($50/ton) and the emissions reductions detailed in Table 7-9.

[e] $\frac{\text{Net Annualized Cost}}{\text{Mg (ton) AN produced per year}}$

[f] $\frac{\text{Net Annualized Cost}}{\text{Mg (ton) of particulates removed per year}}$

[g] $\frac{\text{Net Annualized Cost of Alternative - Net Annualized Cost for Existing Control}}{\text{Mg (ton) particulates removed by alternative - Mg (ton) particulates removed by ELOC}}$

*ELOC = Existing Level of Control

C_x = Net annualized cost to remove a quantity of pollutant (P_x) by alternative x.

C_E = Net annualized cost to remove a quantity of pollutant (P_E) to meet the specified existing level of control.

Cost effectiveness values indicate that Alternative 3, Alternative 1, and Alternative 2 are the most cost effective alternatives for high density prilling, low density prilling and granulation plants, respectively.

7.1.2.6 Base Cost of Facility. To provide a perspective in which control costs can be viewed, capital and annual cost for the entire ammonium nitrate plants are presented. Table 7-12 provides the base capital and annual cost of ammonium nitrate plants for the range of plant sizes investigated. All costs are installed costs, and all facilities are uncontrolled.

Capital costs of the plants were based upon plant costs obtained from published sources and cost estimating manuals.[22,23] These costs are for the entire plant, which include solution formation, concentration, and solids formation equipment. Costs are given for various model plant sizes, but no differentiation is made between low density prilling, high density prilling and drum granulation.

The average total capital investment for new ammonium nitrate plants ranged from \$3.54 million for a 181 Mg/day (200 TPD) facility to \$9.48 million for a 1089 Mg/day (1200 TPD) facility.

The annual cost for ammonium nitrate plants was based upon information obtained from an economic analysis of water pollution regulations.[24] This economic analysis presents annual costs as percentages of annual sales. From this source it was determined that a small 181 Mg/day (200 TPD) facility spends 99 percent of the sales value of the product on annual expenses. For a large 1089 Mg/day (1200 TPD) plant, operating costs amount to 74 percent of the sales value of the product. The annual cost for operation of the ammonium nitrate plants ranges from \$5.80 million for a 181 Mg/day (200 TPD) facility to \$26.00 million for a 1089 Mg/day (1200 TPD) facility.

TABLE 7-12. BASE COSTS OF AMMONIUM NITRATE PLANTS[10,22,23]

Plant Size Mg/Day (TPD)	Capital Cost		Annual Cost $ Millions
	Cost Range ($ millions)	Average Cost ($ millions)	
181 (200)	2.95 - 4.13	3.54	5.80
363 (400)	4.01 - 5.90	4.96	10.90
726 (800)	6.12 - 9.09	7.61	19.40
816 (900)	6.72 - 9.68	7.95	21.10
1089 (1200)	7.39 - 11.60	9.48	26.00

7.1.3 Existing Facilities

Substantial costs could be incurred by applying these control alternatives to existing facilities. Existing facilities may not have the space to install the required pollution control equipment where it is needed. Room may have to be made for new control equipment, either by moving process components or installing pollution control equipment in the available space and ducting the emissions to the process. Both of these alternatives would incur additional costs.

Installation costs for pollution control equipment could be more expensive for existing facilities than for new facilities. Installation of a collection hood within an existing prill tower, for example, may require partial dismantling of the prill tower to install the device, thus increasing installation costs. In addition, existing facilities might have to be reinforced to support the weight of the pollution control equipment; this, too, would increase installation costs. Since these costs are site specific, no costs were determined for applying these controls to existing facilities.

7.2 OTHER COSTS CONSIDERATIONS

7.2.1 Costs Imposed by Water Pollution Control Regulations

Possible sources of wastewater in ammonium nitrate plants are the condensate from the neutralizer and evaporator exhausts and solutions from air pollution control equipment. No wastewater is generated from the solids forming processes, and any effluents from the air pollution control equipment are always recycled to the process for economic reasons.[26] Thus, no additional wastewater treatment costs are expected due to the air pollution control equipment.

7.2.2 Costs Imposed by Solid Waste Disposal Requirements

Because of to the high solubility of ammonium nitrate, any solid wastes can be dissolved and used as liquid fertilizer, or be dissolved and recycled to produce more solids. Thus, no solid process waste is anticipated from an ammonium nitrate plant.

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APPENDIX A

Summary of Test Data

Six ammonium nitrate plants were tested by the EPA to evaluate emissions and control techniques at solid ammonium nitrate production facilities. A description of each plant, its major emission points, and the operations tested are presented in this Appendix. The facilities tested at the plants are listed below:

Plant A
- Neutralizer scrubber inlet and outlet
- Calandria evaporator outlet
- Combined calandria - air swept falling film evaporator outlet
- High density prill tower scrubber inlet and outlet
- Rotary drum cooler scrubber inlet and outlet

Plant B
- Rotary drum granulator scrubber inlet and outlet
- Rotary drum cooler outlet

Plant C
- Rotary drum predryer outlet
- Rotary drum dryer outlet
- Rotary drum cooler outlet

Plant D
- Air swept falling film evaporator outlet
- Combined evaporator - pan granulator scrubber inlet and outlet
- Rotary drum precooler outlet
- Chain mill (crusher) outlet
- Combined precooler - chain mill scrubber outlet
- Rotary drum cooler outlet

Plant E
- Rotary drum cooler scrubber inlet and outlet

Plant Z
- Low density prill tower scrubber inlet and outlet and bypass
- Rotary drum predryer outlet

Rotary drum dryer outlet
Combined predryer - dryer scrubber outlet
Fluidized bed cooler scrubber inlet and bypass

Three tests were performed on each of these facilities to determine ammonium nitrate (AN) particulate and ammonia mass emissions. All the ammonium nitrate and ammonia emission data presented in this Appendix were determined by using a modified EPA Reference Method 5, which is described in detail in Appendix B. Ammonium nitrate emissions were determined with a specific ion electrode which analyzes for nitrate ions. The total ammonia concentration was determined with a specific ion electrode or by direct nesslerization (a colorimetric method). The amount of ammonia emitted was determined by taking the difference of total ammonia and nitrate results. All tests were performed at facilities that operate with an excess of ammonia.

In addition to ammonium nitrate and ammonia, magnesium mass emissions were measured at the prill tower scrubber inlet and outlet at Plant A. EPA Test Methods 1 through 4 were used to determine other characteristics of the gas stream, sampling points, gas velocity, volumetric flowrate and gas moisture content, required for mass emission determinations. Scrubber discharge stacks were monitored by using EPA Reference Method 9 to determine the opacity of the emissions.

The inlets to most of the scrubbers were tested to determine particle size distributions. Cascade impactors made by several manufacturers were used during this testing program. The methods used to determine particle size distributions conformed to the specific manufacturer's recommended procedures and requirements of the Emission Measurement Branch of EPA.

A.1 Plant A[1]

A.1.1 Process Overview

Plant A produces high density ammonium nitrate prills and various types of ammonium nitrate solutions. The plant was designed to produce 567 Mg/day (625 TPD) of prilled ammonium nitrate.

Two parallel neutralizers are fed nitric acid and ammonia or ammonia rich off-gases from the on-site, once-through urea solution plant, and produce an 85 percent ammonium nitrate solution. This ammonium nitrate solution is concentrated to 99+ percent in two stages of concentration. The first stage is a steam heated calandria and the second stage is an air swept falling film evaporator. A magnesium nitrate additive produced in a reactor is injected between the two stages of concentration.

The 99+ percent ammonium nitrate melt from the evaporators is sprayed down through the prill tower, where the droplets are cooled and solidified into prills by a countercurrent induced air flow. The prills are then conveyed to a rotary drum cooler, which reduces the temperature and removes nominal amounts of moisture from the prills by using a countercurrent flow of heat-tempered, refrigerated air. Prills are then screened; product sized prills are either bulk loaded or bagged, and off-size prills are recycled to a weak scrubber liquor evaporator. A calandria evaporator is used to concentrate recycled scrubber liquor and redissolved offsize product rejected from the screening operation.

A.1.2 Emission Control Equipment

The emission control equipment used at Plant A is summarized below. Each neutralizer uses an internal Brinks H-V mist eliminator, followed by a venturi scrubber and a cyclonic separator. Emissions from the two evaporators are normally ducted to a Koch valve tray scrubber along with the prill tower emissions. Emissions from the recycle liquor calandria evaporator and the magnesium additive reactor are usually ducted to the Koch valve tray scrubber, too. However, during this testing program only prill tower emissions were controlled by the Koch valve tray scrubber; all other facilities normally controlled by this scrubber were vented to the atmosphere. Prill tower emissions are ducted down from the top of the prill tower to the Koch scrubber located at ground level.

Exhaust from the rotary drum cooler is divided into two streams; each stream enters a separate spray chamber scrubber. The air exiting each spray chamber is again divided into two streams, each of which enters a separate cyclonic separator. The four separator outlets are then combined into two before being discharged to the atmosphere. The screening, conveying, and bagging areas are all uncontrolled.

A.1.3 Facilities Tested

The facilities tested at Plant A are listed below:

Neutralizer scrubber inlet and outlet
Calandria evaporator outlet
Combined calandria and air swept falling film evaporator outlet
Prill tower Koch valve tray scrubber inlet and outlet
Prill cooler spray chamber inlet and cyclonic separator outlets

Opacity observations and particle size measurements were performed at some of the facilities. Particle size was measured with a Sierra Cascade Impactor, but all of the particulate matter was caught in the pre-collector. Thus, no reliable size distribution information was obtained. A discussion of the testing at each facility follows, including any problems that occurred during testing.

A.1.3.1 Neutralizer

The results of the mass emission tests performed at the inlet and outlet of the neutralizer venturi scrubber are presented in Tables A-1a and A-1b. EPA test methods for high water content gas streams were followed. The combined opacity of the two neutralizer scrubber plumes were monitored and are presented in Table A-2. No opacity was observed from this scrubber.

There were several problems encountered during the neutralizer scrubber tests. A leak check of the sampling train after the first inlet run revealed a significant leak; as a result, the Run No. 1 inlet sample volume and flow rate are not included in the averages. Runs No. 2 and 3 had relatively high isokinetic percents.

The ammonium nitrate (AN) emissions reported here may be somewhat higher than what actually exists because of interference in the nitrate ion analysis. The specific ion electrode analysis (SIE) method used to detect nitrate ion concentration is subject to positive error if the background ion concentration is high relative to the nitrate concentration. The very high concentration of NH_3 compared to AN in the neutralizer gas stream could be sufficient to produce a positive interference in the AN analysis. Also, ammonia emissions out of the scrubber were greater than ammonia emissions entering the scrubber. This implies that ammonia is stripped out of the scrubber liquor; the reason for this is unclear.

A.1.3.2 Calandria Evaporator Outlet

Only mass emission tests were performed at the calandria evaporator outlet. The results of these tests are presented in Tables A-3a and A-3b. Due to the extremely high moisture content in this duct, the sampling was limited to the use of an in-stack orifice on one port and only one sampling point at the center of the duct.

There was an excessive amount of NH_3 compared to AN in this outlet, which may have created interference in the SIE analysis, causing the AN emissions to be excessively high.

A.1.3.3 Combined Calandria and Air Swept Falling Film Evaporator Outlet

Results of the mass emission tests at the combined calandria and air swept falling film evaporator outlet are presented in Tables A-4a and A-4b. A major discrepancy exists in the mass emission results obtained from the calandria outlet and the combined calandria and air swept falling film evaporator outlet. The emissions from the calandria outlet were much higher than the emissions from the combined calandria and air swept falling film evaporator outlet. This is probably due to interference in the SIE analysis, resulting from the high NH_3 concentration at these test points.

A.1.3.4 Prill Tower Koch Valve Tray Scrubber Inlet and Outlet

The inlet and outlet of the Koch Scrubber was tested for magnesium emissions along with ammonium nitrate and ammonia. The results of these tests are presented in Tables A-5a and A-5b. Visible emissions from the scrubber discharge stack were also monitored. These opacity readings are presented in Table A-6.

During testing, isokinetic percentages for the prill tower scrubber outlet test Runs No. 1 and 2 were relatively high; this was probably due to an operator error. The ammonia emissions for Run 3 are anomalously low and are not included in the average of the ammonia data. The low emissions were probably due to the fact that the ammonia injection mechanism was off during this run.

A.1.3.5 Prill Cooler Scrubber Inlet and Outlet

The results of testing at the prill cooler inlet and outlet are presented in Tables A-7a and A-7b. Emissions from the two cyclone separator outlets were combined to determine the total outlet emissions. Since the flow rates from these two scrubbers were not equal, the emissions from the combined outlet were calculated by using a weighted average based on flow rates. The opacity of the two prill cooler scrubber systems exhaust plumes were monitored simultaneously. The results of the opacity readings are presented in Table A-8. No problems were encountered during testing at this scrubber.

A.1.4 Process Operation During Testing

The process was operating at 61 to 81 percent of design capacity during testing.

Several problems occurred during the testing program. The pH in the neutralizer required constant monitoring and adjusting and the prill tower NH_3 injection mechanism was off during Run No. 3 of the prill tower tests. Also, there were problems with the CO_2 compressor in the urea plant which caused the plant to shut down.

Therefore, the NH_3 feed to the neutralizer had to be supplied from the NH_3 vaporizers, instead of from the urea NH_3 rich off gas. This problem occurred before the third test of the prill tower scrubber and was corrected before the third test started. Finally, a decreased production demand led to a substantial production reduction in the air swept falling film evaporator between test 1 and 2 on this unit.

TABLE A-1a. PLANT A: SUMMARY OF EMISSION TEST RESULTS FOR THE NEUTRALIZER SCRUBBER (METRIC)

Test No.	1[a]	2	3	Ave.
General Data				
Date	6/19/79	6/20/79	6/20/79	
Isokinetic (%) In/Out	92.74/110.1	113.7/114.9	126.6/112.8	120.2[b]/112.6
Production Rate (Mg/hr)	10.2	10.5	10.4	10.4
Ambient Temp. (K)	309	303	305	306
Relative Humidity	34	57	58	50
Exhaust Characteristics				
Flowrate inlet:	.7887	8.938	7.383	8.162[b]
(dnm^3/min) outlet:	10.71	8.555	9.241	9.502
Temperature inlet:	405	408	405	406
(K) outlet:	374	373	372	373
Moisture (% vol) inlet:	99.53	94.43	95.24	94.84
outlet:	94.23	95.01	94.85	94.70
Control Device Characteristics				
Device Type	Venturi - cyclonic separator scrubber			
Pressure Drop (kPa)	12.4	16.1	14.2	14.2
Liquor pH (Ave.)	8.73	8.80	8.89	8.81
Liquor AN Conc. (%) (Ave.)	6.6	7.1	7.3	7.0
Ammonium Nitrate Emissions				
Particulate Conc. inlet:	681.0	53.27	62.83	55.60[b]
(g/dnm^3) outlet:	2.542	2.492	2.144	2.400
Emission Rate inlet:	32.22	28.57	27.83	27.23
(kg/hr) outlet:	1.696	1.321	1.226	1.416
Emission Factor inlet:	3.1434	2.7385	2.6913	2.6329
(g/kg) outlet:	0.16542	0.12663	0.11862	0.13693
Collection Efficiency (%)	94.7	95.4	95.6	94.8
Ammonia Emissions				
Ammonia Conc. inlet:	285.3	398.5	529.7	379.0
(g/dnm^3) outlet:	220.4	412.2	593.1	400.3
Emission Rate inlet:	134.9	213.6	234.4	185.4
(kg/hr) outlet:	146.9	221.9	339.1	240.0
Emission Factor inlet:	13.2	20.5	22.7	17.9
(g/kg) outlet:	14.3	20.9	32.8	22.8
Collection Efficiency (%)	Negative	Negative	Negative	Negative

[a] Sample train leak during Run 1.

[b] Includes Run 2 and 3 only due to leak in Run 1.

TABLE A-1b. PLANT A: SUMMARY OF EMISSION TEST RESULTS FOR THE NEUTRALIZER SCRUBBER (ENGLISH)

Test No.		1[a]	2	3	Ave.
General Data					
Date		6/19/79	6/20/79	6/20/79	
Isokinetic (%) In/Out		92.74/110.1	113.7/114.9	126.6/112.8	120.2[b]/112.6
Production Rate Tons/hr		11.3	11.5	11.4	11.4
Ambient Temp. °F		96	86	89	90
Relative Humidity		34	57	58	50
Exhaust Characteristics					
Flowrate	inlet:	27.85	315.6	260.7	288.2[b]
(dscfm)	outlet:	378.3	302.1	326.3	335.6
Temperature	inlet:	269	275	270	271
(F°)	outlet:	213	212	210	212
Moisture (% vol)	inlet:	99.53	94.43	95.24	94.84
	outlet:	94.23	95.01	94.85	94.70
Control Device Characteristics					
Device Type		Venturi - cyclonic separator scrubber			
Pressure Drop (in. W.G.)		49.7	64.5	57.2	57.1
Liquor pH (Ave.)		8.73	8.80	8.89	8.81
Liquor AN Conc. (%) (Ave.)		6.6	7.1	7.3	7.0
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	297.6	23.28	27.46	24.30[b]
(gr/dscf)	outlet:	1.111	1.089	.9370	1.049
Emission Rate	inlet:	71.04	62.98	61.36	60.03
(lb/hr)	outlet:	3.739	2.912	2.704	3.121
Emission Factor	inlet:	6.2867	5.4765	5.3825	5.2658
(lb/ton)	outlet:	0.33088	0.25326	2.23723	0.27378
Collection Efficiency (%)		94.7	95.4	95.6	94.8
Ammonia Emissions*					
Ammonia Conc.	inlet:	124.6	174.0	231.3	165.5
(gr/dscf)	outlet:	96.25	180.0	259.0	174.8
Emission Rate	inlet:	297.4	470.8	516.8	408.7
(lb/hr)	outlet:	323.9	489.1	747.6	529.0
Emission Factor	inlet:	26.32	40.94	45.33	35.85
(lb/ton)	outlet:	28.67	41.85	65.59	45.63
Collection Efficiency		Negative	Negative	Negative	Negative

[a] Sample train leak during Run 1.

[b] Includes Run 2 and 3 only, due to leak in Run 1.

TABLE A-2. PLANT A: OPACITY READINGS ON THE TWO NEUTRALIZER SCRUBBER STACKS

Date	Location	Time	Average Opacity For 6 Minutes (Combined Plumes)
6-19-79	A	0930-0935	0
		0936-0941	0
		0942-0947	0
		0948-0953	0
		0954-0959	0
		1000-1005	0
		1006-1011	0
		1012-1017	0
		1018-1023	0
		1024-1029	0
		1030-1035	0
		1036-1041	0
		1042-1047	0
		1048-1053	0
		1054-1059	0
		1100-1105	0
		1106-1111	0
		1112-1117	0
		1118-1123	0
		1124-1129	0
6-19-79	B	1530-1535	0
		1536-1541	0
		1542-1547	0
		1548-1553	0
		1554-1559	0
		1600-1605	0
		1606-1611	0
		1612-1617	0
		1618-1623	0
		1624-1629	0
6-20-79	A	1330-1335	0
		1336-1341	0
		1342-1347	0
		1348-1353	0
		1354-1359	0
		1400-1405	0
		1406-1411	0
		1412-1417	0
		1418-1423	0
		1424-1429	0
6-22-79	C	1400-1405	0
		1406-1411	0
		1412-1417	0
		1418-1423	0
		1424-1429	0
		1430-1435	0
		1436-1441	0
		1442-1447	0
		1448-1453	0
		1454-1459	0

TABLE A-3a. PLANT A: SUMMARY OF EMISSION TEST RESULTS AT THE CALANDRIA EVAPORATOR OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	6/22/79	6/22/79	6/22/79	
Isokinetic (%)	98.3	105.1	104.1	102.5
Production Rate (Mg/hr)	15.6	15.9	16.1	15.9
Ambient Temp. (K)	301	304	306	304
Ambient Moisture (%) Relative Humidity	67	49	44	53
Exhaust Characteristics				
Flowrate (dnm^3/min)	0.234	0.235	0.291	0.253
Temperature (K)	416	417	416	416
Moisture (% Vol.)	99.77	99.78	99.73	99.76
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	122.55	119.3	132.2	125.2
Emission Rate (kg/hr)	1.720	1.679	2.307	1.902
Emission Factor (g/kg)	0.1102	0.1058	0.1437	0.1198
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	1484.4	1279.4	1506.8	1428.3
Emission Rate (kg/hr)	20.85	18.01	26.30	21.70
Emission Factor (g/kg)	1.336	1.1345	1.638	1.367

TABLE A-3b. PLANT A: SUMMARY OF EMISSION TEST RESULTS AT THE CALANDRIA EVAPORATOR OUTLET (ENGLISH)

Test No.	1	2	3	4
General Data				
Date	6/22/79	6/22/79	6/22/79	
Isokinetic (%)	98.3	105.1	104.1	102.5
Production Rate Tons/hr	17.2	17.5	17.7	17.5
Ambient Temp. °F	82	88	92	87
(%) Relative Humidity	67	49	44	53
Exhaust Characteristics				
Flowrate (dscfm)	8.272	8.291	10.280	8.948
Temperature (F°)	289	291	290	290
Moisture (% Vol.)	99.77	99.78	99.73	99.76
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	53.48	52.09	57.72	54.68
Emission Rate (lb/hr)	3.792	3.702	5.086	4.194
Emission Factor (lb/ton)	0.22047	0.21154	0.28734	0.23966
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	648.2	558.7	658.0	623.7
Emission Rate (lb/hr)	45.96	39.70	57.98	47.84
Emission Factor (lb/ton)	2.672	2.269	3.276	2.734

TABLE A-4a. PLANT A: SUMMARY OF EMISSION TEST RESULTS AT THE COMBINED CALANDRIA AND AIR SWEPT FALLING FILM EVAPORATOR OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	6/22/79	6/22/79	6/22/79	
Isokinetic (%)	113.2	127.5	111.4	117.4
Production Rate (Mg/hr)	18.4	19.1	19.1	18.7
Ambient Temp. (K)	301	304	306	304
(%) Relative Humidity	67	49	44	53
Exhaust Characteristics				
Flowrate (dnm^3/min)	90	77	91	86
Temperature (K)	428	429	430	429
Moisture (% Vol.)	32.45	43.38	35.71	37.18
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	0.2565	0.2739	0.2638	0.2647
Emission Rate (kg/hr)	1.392	1.269	1.439	1.369
Emission Factor (g/kg)	0.0756	0.0666	0.0756	0.0726
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	14.78	12.42	18.37	15.22
Emission Rate (kg/hr)	80.2	57.5	100.2	78.7
Emission Factor (g/kg)	4.357	3.019	5.255	4.171

TABLE A-4b. PLANT A: SUMMARY OF EMISSION TEST RESULTS AT THE COMBINED CALANDRIA AND AIR SWEPT FALLING FILM EVAPORATOR OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	6/22/79	6/22/79	6/22/79	
Isokinetic (%)	113.2	127.5	111.4	117.4
Production Rate Tons/hr	20.3	21.0	21.0	20.8
Ambient Temp. °F	82	88	92	87
(%) Relative Humidity	67	49	44	53
Exhaust Characteristics				
Flowrate (dscfm)	3196	2728	3213	3046
Temperature (F°)	311	313	315	313
Moisture (% Vol.)	32.45	43.38	35.71	37.18
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	0.1120	0.1196	0.1152	0.1156
Emission Rate (lb/hr)	3.068	2.797	3.173	3.018
Emission Factor (lb/ton)	0.15113	0.13319	0.15110	0.14510
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	6.458	5.423	8.02	6.646
Emission Rate (lb/hr)	176.9	126.8	220.8	173.5
Emission Factor (lb/ton)	8.714	6.038	10.51	8.341

TABLE A-5a. PLANT A: SUMMARY OF EMISSION TEST RESULTS FOR THE PRILL TOWER SCRUBBER (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	5/8/79	5/8/79	5/9/79	
Isokinetic (%) In/Out	99.3/108.4	98.9/110.8	99.3/103.5	99.2/107.6
Production Rate (Mg/hr)	19.1	19.1	19.3	19.2
Ambient Temp. (K)	299	298	299	299
Relative Humidity	60	60	65	62
% Opacity	12.8	15.2	17.2	15.1
Exhaust Characteristics				
Flowrate inlet:	7300	7190	7320	7270
(dnm^3/min) outlet:	7510	7470	7600	7530
Temperature inlet:	307	306	306	306
(K) outlet:	309	308	306	308
Moisture (% vol) inlet:	2.049	2.466	2.542	2.352
outlet:	3.033	2.56	2.874	2.822
Control Device Characteristics				
Device Type	Koch Valve Tray Scrubber			
Pressure Drop	2.64	2.71	2.66	2.66
Liquor pH (Ave.)	7.21	7.28	6.50	7.00
Liquor AN Conc. (%) (Ave.)	34	35	27	32
Ammonium Nitrate Emissions				
Particulate Conc. inlet:	0.07175	0.06816	0.07228	0.07075
(g/dnm^3) outlet:	0.03512	0.03446	0.03794	0.03585
Emission Rate inlet:	31.43	29.41	31.75	30.86
(kg/hr) outlet:	15.82	15.43	17.31	16.16
Emission Factor inlet:	1.650	1.544	1.643	1.612
(g/kg) outlet:	0.831	0.811	0.896	0.844
Collection Efficiency (%)	49.7	47.5	45.5	47.6
Ammonia Emissions*				
Ammonia Conc. inlet:	1.2610	1.2641	0.0460	1.2568
(g/dnm^3) outlet:	0.1988	0.1806	0.0632	0.1920
Emission Rate inlet:	552.0	545.2	20.2	547.5
(kg/hr) outlet:	89.5	80.9	28.8	86.7
Emission Factor inlet:	28.98	28.61	1.05	28.6
(g/kg) outlet:	4.70	4.24	1.49	4.53
Collection Efficiency (%)	83.8	85.2	Negative	84.2
Magnesium Emissions				
Magnesium Conc. inlet:	0.0006256	0.0002097	0.0002659	0.0003652
(g/dnm^3) outlet:	0.0001113	0.00006295	0.0001194	0.0000974
Emission Rate inlet:	0.2740	0.0905	0.1168	0.1593
(kg/hr) outlet:	0.0501	0.0282	0.0545	0.0440
Emission Factor inlet:	0.01438	0.00475	0.00605	0.00832
(g/kg) outlet:	0.00263	0.00148	0.00282	0.00230
Collection Efficiency (%)	81.7	68.8	53.3	72.4

*Run 3 results were low and were not included in the average.

TABLE A-5b. PLANT A: SUMMARY OF EMISSION TEST RESULTS FOR THE PRILL TOWER SCRUBBER (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		5/8/79	5/8/79	5/9/79	
Isokinetic (%) In/Out		99.3/108.4	99.8/110.8	99.3/103.5	99.2/107.6
Production Rate Tons/hr		21.0	21.0	21.3	21.1
Ambient Temp. °F		78	77	78	78
Relative Humidity		60	60	65	62
% Opacity		12.8	15.2	17.2	15.1
Exhaust Characteristics					
Flowrate	inlet:	257,800	253,900	258,500	256,700
(dscfm)	outlet:	265,200	263,700	268,500	256,800
Temperature	inlet:	93	91	91	92
(F°)	outlet:	96	95	91	94
Moisture (% vol)	inlet:	2.049	2.466	2.542	2.352
	outlet:	3.033	2.56	2.874	2.822
Control Device Characteristics					
Device Type		Koch Valve Tray Scrubber			
Pressure Drop (in. W.G.)		10.6	10.9	10.7	10.7
Liquor pH (Ave.)		7.21	7.28	6.50	7.00
Liquor AN Conc. (%) (Ave.)		34	35	27	32
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	0.03136	0.02979	0.03159	0.03092
(gr/dscf)	outlet:	0.01535	0.01506	0.01658	0.01565
Emission Rate	inlet:	69.29	64.83	69.99	68.02
(lb/hr)	outlet:	34.88	34.02	38.16	35.64
Emission Factor	inlet:	3.299	3.087	3.286	3.224
(lb/ton)	outlet:	1.661	1.620	1.792	1.688
Collection Efficiency (%)		49.7	47.5	45.5	47.6
Ammonia Emissions*					
Ammonia Conc.	inlet:	0.5506	0.5520	0.0201	0.5488
(gr/dscf)	outlet:	0.08680	0.07886	0.02760	0.08386
Emission Rate	inlet:	1217	1202	44.55	1207
(lb/hr)	outlet:	197.3	178.3	63.53	191.1
Emission Factor	inlet:	57.95	57.22	2.092	57.21
(lb/ton)	outlet:	9.40	8.48	2.98	9.05
Collection Efficiency (%)		83.8	85.2	Negative	84.2
Magnesium Emissions					
Magnesium Conc.	inlet:	0.0002734	0.00009165	0.0001162	0.0001596
(gr/dscf)	outlet:	0.0004862	0.00002751	0.00005217	0.00004256
Emission Rate	inlet:	0.6041	0.1995	0.25747	0.35116
(lb/hr)	outlet:	0.1105	0.06218	0.12007	0.09696
Emission Factor	inlet:	0.02877	0.00950	0.01209	0.01664
(lb/ton)	outlet:	0.00526	0.00296	0.00564	0.00460
Collection Efficiency (%)		81.7	68.8	53.3	72.4

*Run 3 results were low and were not included in the average.

TABLE A-6. PLANT A. OPACITY READINGS ON THE PRILL TOWER SCRUBBER OUTLET

Date	Run Number	Time	Average Opacity For 6 Minutes	Date	Run Number	Time	Average Opacity For 6 Minutes
5-7 79	NA	1400-1405	2.3	5-8-79	2	1500-1505	15.4
		1406-1411	7.7			1506-1511	15.8
		1412-1417	6.3			1512-1517	15.0
		1418-1423	8.8			1518-1523	15.4
		1424-1429	6.5			1524-1529	17.1
		1430-1435	5.4			1530-1535	14.8
		1436-1441	6.6			1536-1541	16.0
		1442-1447	6.6			1542-1547	14.6
		1448-1453	5.6			1548-1553	14.6
		1454-1459	4.8			1554-1559	14.8
		1505-1510	7.5			1605-1610	11.3
		1511-1516	8.8			1611-1616	11.7
		1517-1522	6.9			1617-1622	11.7
		1523-1528	5.4			1623-1628	16.5
		1529-1534	5.4			1629-1634	15.6
		1535-1540	7.7			1635-1640	16.6
		1541-1546	8.3			1641-1646	16.3
		1547-1552	2.3			1647-1652	16.9
		1553-1558	5.0			1653-1658	16.7
		1559-1604	6.5			1659-1704	16.7
		Average	6.2			Average	15.2
5-8-79	1	1030-1035	11.6	5-9-79	3	1050-1056	18.3
		1115-1120	14.6			1057-1102	14.2
		1121-1126	14.4			1103-1108	17.9
		1127-1132	14.2			1109-1114	17.1
		1133-1138	12.5			1115-1120	17.7
		1139-1144	11.6			1121-1126	18.3
		1145-1150	12.5			1127-1132	19.0
		1151-1157	13.8			1133-1138	17.5
		1157-1202	11.7			1139-1144	14.8
		1103-1208	11.3			1145-1150	17.3
		Average	12.8			Average	17.2

TABLE A-7a. PLANT A: SUMMARY OF EMISSION TEST RESULTS FOR COOLER SCRUBBER (METRIC)

Test No.		1	2	3	Ave.
General Data					
Date		5/10/79	5/11/79	5/11/79	
Isokinetic (%)		99.3/97.8	99.6/100.7	98.2/101.7	99.0/100.1
Production Rate (Mg/hr)		19.1	19.1	18.8	19.0
Ambient Temp. (K)		308	305	310	308
% Relative Humidity		45	50	37	44
Exhaust Characteristics					
Flowrate	inlet:	896	881	878	885
(dnm^3/min)	outlet:	974	953	939	956
Temperature	inlet:	62	63	63	63
(K)	outlet:	48	46	48	48
Moisture (% Vol.)	inlet:	1.879	1.447	0.755	1.360
	outlet:	2.290	3.182	2.428	2.634
Control Device Characteristics					
Device Type		Spray Chamber - Buell Cyclonic Separator			
Pressure Drop (kPa)		1.02	0.995	0.970	0.995
Liquor pH (Ave.)		6.37	6.46	6.45	6.43
Liquor AN Conc. (%)(Ave.)		0.23	0.25	0.32	0.26
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	0.2803	0.2787	0.3286	0.2956
(g/dnm^3)	outlet:	0.0222	0.03613	0.0154	0.02467
Emission Rate	inlet:	15.07	14.74	17.32	15.70
(kg/hr)	outlet:	1.299	2.067	0.867	1.414
Emission Factor	inlet:	0.791	0.774	0.923	0.828
(g/kg)	outlet:	0.0682	0.1085	0.04618	0.0746
Collection Efficiency (%)		91.4	86.0	95.0	91.0
Ammonia Emissions					
Ammonia Conc.	inlet:	negative	0.00827	0.0112	0.00965
(g/dnm^3)	outlet:	0.00405	0.00902	0.0119	0.00829
Emission Rate	inlet:	negative	0.4372	0.5905	0.5124
(kg/hr)	outlet:	0.11721	0.2586	0.3331	0.2371
Emission Factor	inlet:	negative	0.02295	0.0315	0.0271
(g/kg)	outlet:	0.0062	0.0136	0.0178	0.0113
Collection Efficiency (%)			40.7	43.6	58.2

TABLE A-7b. PLANT A: SUMMARY OF EMISSION TEST RESULTS FOR COOLER SCRUBBER (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		5/10/79	5/11/79	5/11/79	
Isokinetic (%) In/Out		99.3/97.8	99.6/100.7	99.2/101.7	99.0/100.1
Production Rate Tons/hr		21	21	20.7	20.9
Ambient Temp. °F		95	89	98	94
(%) Relative Humidity		45	50	37	44
Exhaust Characteristics					
Flowrate	inlet:	31650	31120	31020	31260
(dscfm)	outlet:	34410	33660	33140	33740
Temperature	inlet:	143	144	145	144
(F°)	outlet:	118	114	118	117
Moisture (% Vol.)	inlet:	1.879	1.447	0.755	1.360
	outlet:	2.290	3.182	2.428	2.634
Control Device Characteristics					
Device Type		Spray Chamber - Buell Cyclonic Separator			
Pressure Drop (in. W.G.) Avg.		4.1	4.0	3.9	4.0
Liquor pH (Ave.)		6.37	6.46	6.45	6.43
Liquor AN Conc. (%) (Ave.)		0.23	0.25	0.32	0.26
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	0.1225	0.1218	0.1436	0.1292
(gr/dscf)	outlet:	0.00971	0.01579	0.00673	0.01078
Emission Rate	inlet:	33.22	32.50	38.19	34.62
(lb/hr)	outlet:	2.864	4.556	1.912	3.118
Emission Factor	inlet:	1.582	1.547	1.845	1.656
(lb/ton)	outlet:	0.1364	0.2169	0.09235	0.1492
Collection Efficiency (%)		91.4	86.0	95.0	91.0
Ammonia Emissions					
Ammonia Conc.	inlet:	negative	0.003613	0.00490	0.00421
(gr/dscf)	outlet:	0.00177	0.00394	0.0052	0.00362
Emission Rate	inlet:	negative	0.9639	1.3017	1.1297
(lb/hr)	outlet:	0.2584	0.5701	0.7343	0.5228
Emission Factor	inlet:	negative	0.0459	0.0629	0.0541
(lb/ton)	outlet:	0.0123	0.0272	0.0355	0.02264
Collection Efficiency			40.7	43.6	58.2

TABLE A-8. PLANT A: OPACITY READINGS ON THE PRILL COOLER EAST AND WEST SCRUBBER OUTLETS

Date	Time	Average Opacity For 6 Minutes (East Outlet/West Outlet)
5-10-79	1100-1105	0/0
	1106-1111	0/0
	1112-1117	0/0
	1118-1123	0/0
	1124-1129	0/0
	1130-1135	0/0
	1136-1141	0/0
	1142-1147	0/0
	1148-1153	0/0
	1154-1159	0/0
	1200-1205	0/0
	1206-1211	0/0
	1212-1217	0/0
	1218-1223	0/0
	1224-1229	0/0
	1230-1235	0/0
	1236-1241	0/0
	1242-1247	0/0
	1248-1253	0/0
	1254-1259	0/0
	1310-1315	0/0
	1316-1321	0/0
	1322-1327	0/0
	1328-1333	0/0
	1334-1339	0/0
	1340-1345	0/0
	1346-1351	0/0
	1352-1357	0/0
	1358-1403	0/0
	1404-1409	0/0

A.2 Plant B[2]

A.2.1 Process Overview

Plant B produces various ammonium nitrate solutions and granulated solid ammonium nitrate. The solids production was designed for 363 Mg/day (400 TPD) of ammonium nitrate.

An 83 percent ammonium nitrate solution is produced in the neutralizer. This solution is split into two streams, with some going to the solution product area; the remainder proceeds to the two-stage concentrator, where the solution is concentrated to 99+ percent. The ammonium nitrate melt from the concentrator is sprayed into the rotary drum granulator. In the granulator a flow of chilled air countercurrent to the granule flow solidifies and cools the granules. A set of screens separates the product size granules from offsize granules. Product size granules proceed to a rotary drum cooler where refrigerated air further cools the granules. The cooled granules are then coated and either bagged or bulk loaded.

A.2.2 Emission Control Equipment

The emission control equipment used at Plant B consists of an entrainment scrubber for granulator exhausts, and wet cyclones for cooler exhausts. Emissions from the neutralizer, concentrators, coater, crushing and screening operations and conveying equipment are discharged to the atmosphere uncontrolled.

This particular rotary drum granulator has been fitted with a "knock out" or "settling" chamber on the end of the drum where the air exits. Some of the ammonium nitrate particulate that would normally go to the scrubber is removed in this chamber. The exhaust from the granulator is then ducted to a Joy "Type D" Turbulaire Scrubber, where it is combined with an ammonium nitrate weak liquor scrubber solution. Emissions from the rotary drum cooler are ducted to two parallel wet cyclones. There is a water spray located in the duct itself and three sprays in each cyclone.

A.2.3 Facilities Tested

Two sources were tested at Plant B, the rotary drum granulator scrubber inlet and outlet, and the rotary drum cooler outlet. A Brinks Impactor was used to determine particle sizes at the cooler outlet and the granulator scrubber inlet. EPA Method 9 was used to observe plume opacity levels from the granulator scrubber exhaust stack.

The results of the mass emission tests on the granulator scrubber are presented in Tables A-9a and A-9b. Particle size results are shown in Figure A-1, and opacity observations are presented in Table A-10. The cooler mass emission test results are given in Table A-11a and A-11b; the particle size results are presented in Figure A-2.

A.2.3.1 Testing Problems

During the testing program, several of the test runs were discontinuous due to the excessive particulate loading at the rotary drum granulator scrubber inlet and the rotary drum cooler outlet sampling locations.

A.2.4 Process Operation During Testing

The process was operating at 87 to 125 percent of design capacity during the testing.

Minor plant upsets occurred during the entire testing program. Problems with controlling the fan damper on the rotary drum granulator and scrubber, and a malfunctioning scrubber liquor level controller voided the first days of testing. On day three (March 7, 1979), only three out of four granulator nozzles were operative due to the limited quantity of ammonium nitrate (AN) melt available. The third particulate concentration test on the inlet and outlet to the rotary drum granulator scrubber was conducted at this lower production rate. The fourth granulator nozzle was brought back on line during the early afternoon and continued on line for the remainder of the testing.

On day four (March 8, 1979), the granulator was put on total recycle, with no additional AN melt being added due to an excessively low level in the head tank. This happened between tests and should not affect the results of the testing of the rotary drum cooler.

On day five (March 9, 1979), the compressor on the inlet air cooler of the granulator went out of service, causing granulator temperatures to become excessively high. Trouble continued with the fan damper serving the granulator and scrubber. The combined effect of these two problems eventually led to a rise in the granulator bed temperature to a point where the granules were agglomerating, forming "rocks". At this point, the granulator was shut down until the problem was corrected. Testing did not resume until steady state conditions were again attained.

TABLE A-9a. PLANT B: SUMMARY OF EMISSION TEST RESULTS FOR THE ROTARY DRUM GRANULATOR SCRUBBER (METRIC)

Test No.		1	2	3	Ave.
General Data					
Date		3/7/79	3/7/79	3/8/79	
Isokinetic (%) In/Out		102.6/98.1	103.1/97.5	101.7/101.9	102.5/99.2
Production Rate (Mg/hr)		13.15	15.82	18.60	15.86
Ambient Temp. (K)		292	298	289	293
(%) Relative Humidity		40	23	41	34.7
Exhaust Characteristics					
Flowrate	inlet:	1,172	1,230	1,391	1,264
(dnm^3/min)	outlet:	1,091	1,158	1,245	1,165
Temperature	inlet:	74	86	82	81
(K)	outlet:	311	316	319	315
Moisture (% vol)	inlet:	2.0	2.0	2.0	2.0
	outlet:	2.9	3.7	7.9	4.8
Control Device Characteristics					
Device Type		Joy "Type D" Turbulair Scrubber			
Pressure Drop (kPa)		2.41	2.54	3.19	2.71
Liquor pH (Ave.)		6.33	5.88	6.51	6.24
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	30.46	31.73	29.11	30.43
(g/dnm^3)	outlet:	0.06	0.040	0.047	0.049
Emission Rate	inlet:	2,141.9	2,341.7	2,429.5	2,304.4
(kg/hr)	outlet:	3.928	2.779	3.511	3.41
Emission Factor	inlet:	162.9	148.0	130.6	147.2
(g/kg)	outlet:	0.299	0.176	0.189	0.221
Collection Efficiency (%)		99.8	99.9	99.8	99.8
Ammonia Emissions*					
Ammonia Conc.	inlet:	15.45	0.2817	1.193	5.640
(dnm^3)	outlet:	0.0183	0.0550	0.270	0.156
Emission Rate	inlet:	1085.7	20.78	99.52	402.0
(kg/hr)	outlet:	6.046	3.810	20.19	11.11
Emission Factor	inlet:	82.55	1.32	5.35	29.74
(g/kg)	outlet:	0.090	0.240	1.085	0.675
Collection Efficiency (%)		99.89*	81.75	79.72	97.7*

*Inlet Run No. 1 acid fraction results are inconsistently higher than other test results, may have had sample carryover in the impinger.

TABLE A-9b. PLANT B: SUMMARY OF EMISSION TEST RESULTS FOR THE ROTARY DRUM GRANULATOR SCRUBBER (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		3/7/79	3/7/79	3/8/79	
Isokinetic (%) In/Out		102.6/98.1	103.1/97.5	101.7/101.9	102.5/99.2
Production Rate Tons/hr		14.5	17.4	20.5	17.5
Ambient Temp. °F		66	76.6	60.9	67.8
(%) Relative Humidity		40	23	41	34.7
Exhaust Characteristics					
Flowrate	inlet:	41,401	43,442	49,120	44,654
(dscfm)	outlet:	38,521	40,887	43,969	41,126
Temperature	inlet:	166	186	180	177
(°F)	outlet:	100	109	115	108
Moisture (% vol)	inlet:	2.0	2.0	2.0	2.0
	outlet:	2.9	3.7	7.9	4.8
Control Device Characteristics					
Device Type		Joy "Type D" Turbulair Scrubber			
Pressure Drop (in. W.G.)		9.7	10.2	12.8	10.9
Liquor pH (Ave.)		6.33	5.88	6.51	6.24
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	13.311	13.868	12.725	13.301
(gr/dscf)	outlet:	0.026	0.017	0.020	0.021
Emission Rate	inlet:	4,723.6	5,163.9	5,357.6	5,081.7
(lb/hr)	outlet:	8.58	5.96	7.54	7.36
Emission Factor	inlet:	325.8	296.8	261.3	294.6
(lb/ton)	outlet:	0.59	0.34	0.37	0.43
Collection Efficiency (%)		99.8	99.9	99.8	99.8
Ammonia Emissions*					
Ammonia Conc.	inlet:	6.745	0.123	0.521	2.463
(gr/dscf)	outlet:	0.008	0.024	0.118	0.068
Emission Rate	inlet:	2,393.6	45.8	219.4	886.3
(lb/hr)	outlet:	2.64	8.4	44.5	24.5
Emission Factor	inlet:	165.1	2.63	10.7	59.48
(lb/ton)	outlet:	0.18	0.48	2.17	1.35
Collection Efficiency (%)		99.89*	81.75	79.72	97.7*

*Inlet Run No. 1 acid fraction results are inconsistently higher than other test results, may have had sample carryover in the impinger.

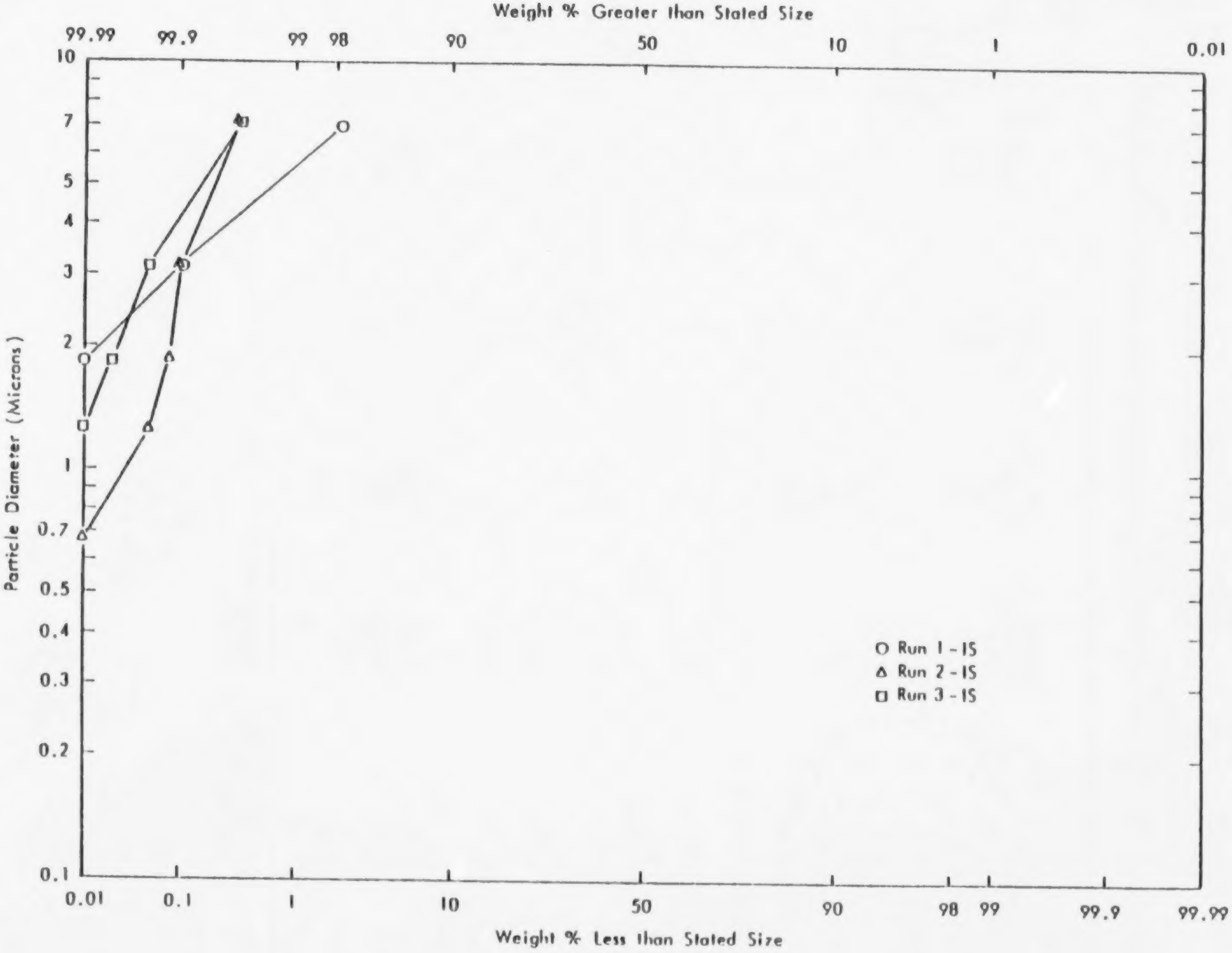

Figure A-1. Plant B: Particle size results at the rotary drum granulator scrubber inlet.

TABLE A-10. PLANT B: OPACITY READINGS FROM THE ROTARY DRUM GRANULATOR SCRUBBER OUTLET STACK

Time	Average opacity for ~ 6 min intervals, (%)	Date
16:40:15-16:46	5.0	03-07-79
16:46:15-16:52	5.0	
16:52:15-16:58	5.0	
16:58:15-17:04	5.0	
17:04:15-17:10	5.2	
17:10:15-17:16	5.4	
17:16:15-17:22	5.2	
17:22:15-17:28	5.6	
Average	5.2	
09:20-09:25:45	12.9	03-08-79
09:26-09:31:45	13.5	
09:32-09:37:45	13.5	
Average	13.3	
09:52:15-09:58	14.0	
09:58:15-10:04	15.8	
10:04:15-10:10	14.8	
10:10:15-10:16	14.4	
10:16:15-10:22	14.8	
10:22:15-10:28	15.4	
Average	14.8	
10:33:45-10:39:30	17.3	
10:39:45-10:45:30	15.0	
10:45:45-10:51:30	15.8	
10:51:45-10:57:30	15.8	
Average	16.0	
11:08:15-11:14	17.9	
11:14:15-11:20	15.6	
Average	16.8	
11:26-11:31:45	15.6	
11:32-11:37:45	14.6	
11:38-11:43:45	12.9	
Average	14.4	
11:50:15-11:56	14.4	
11:56:15-12:02	15.0	
12:02:15-12:08	14.2	
12:08:15-12:14	16.5	
12:14:15-12:20	17.5	
12:20:15-12:26	13.1	
12:26:15-12:32	13.8	
12:32:15-12:38	13.5	
12:38:15-12:44	12.1	
12:44:15-12:50	13.1	
12:50:15-12:56	14.4	
12:56:15-13:02	13.8	
Average	14.3	
13:35-13:40:45	19.4	
13:41-13:46:45	15.0	
13:47-13:52:45	14.4	
13:53-13:58:45	17.1	
Average	16.5	
14:03-14:08:45	15.4	
14:09-14:14:45	16.3	
14:15-14:20:45	17.3	
14:21-14:26:45	12.9	
14:27-14:32:45	14.6	
Average	15.3	
14:33-14:38:45	14.9	
14:39-14:44:45	15.3	
14:45-14:50:45	16.3	
14:51-14:56:45	13.5	
Average	15.1	

* Opacity observations recorded from the rotary drum granulator scrubber outlet stack correspond to MRI test 1-GRDC at the uncontrolled outlet of the rotary drum cooler.

TABLE A-11a. PLANT B: SUMMARY OF EMISSION TEST RESULTS AT THE COOLER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	3/8/79	3/9/79	3/9/79	
Isokinetic (%)	93.7	100.7	100.4	98.3
Production Rate (Mg/hr)	18.96	18.87	18.96	18.93
Ambient Temp. (K)	297	296	298	297
(%) Relative Humidity	29	71	55	52
Exhaust Characteristics				
Flowrate (dnm^3/min)	579	565	556	567
Temperature (K)	310	315	317	314
Moisture (% vol)	2.1	1.5	1.8	1.8
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	4.354	3.970	4.178	4.167
Emission Rate (kg/hr)	151.3	134.6	139.4	141.8
Emission Factor (g/kg)	8.0	7.1	7.4	7.5
Ammonia Emissions[a]				

[a] Ammonia emissions are all negative, there were more nitrate than ammonia ions present.

TABLE A-11b. PLANT B: SUMMARY OF EMISSION TEST RESULTS AT THE COOLER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	3/8/79	3/9/79	3/9/79	
Isokinetic (%)	93.7	100.7	100.4	98.3
Production Rate Tons/hr	20.85	20.82	20.85	20.84
Ambient Temp. °F	75.3	73.0	77.3	75.2
(%) Relative Humidity	29	71	55	52
Exhaust Characteristics				
Flowrate (dscfm)	20,464	19,948	19,620	20,011
Temperature (F°)	99	107	111	106
Moisture (% vol)	2.1	1.5	1.8	1.8
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	1.903	1.735	1.826	1.321
Emission Rate (lb/hr)	333.8	296.7	307.1	312.5
Emission Factor (lb/ton)	16.0	14.3	14.7	15.0
Ammonia Emissions[a]				

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[a] Ammonia emissions are all negative, there were more nitrate than ammonia ions present.

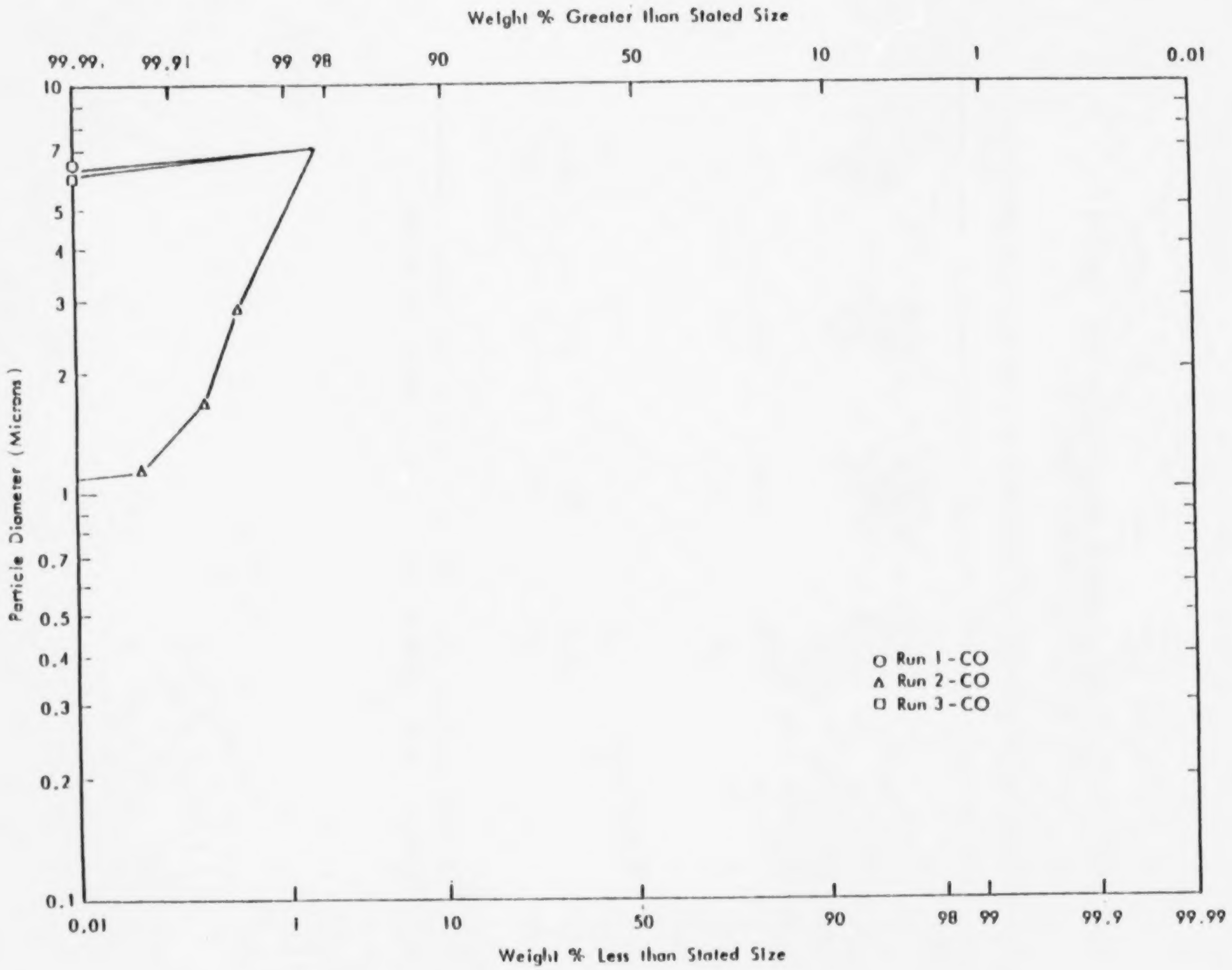

Figure A-2. Plant B: Particle size results at the rotary drum cooler outlet.

A.3 Plant C[3]

A.3.1 Process Overview

Plant C produces ammonium nitrate solutions and low density ammonium nitrate prills. The plant was designed for a production rate of 161 Mg/day (200 TPD) of prilled ammonium nitrate.

The 83 percent ammonium nitrate solution from the neutralizer is concentrated to 95 percent in a vacuum evaporator. The 95 percent ammonium nitrate melt is then pumped to the top of the prill tower, where it is sprayed down through multiple spray heads. Prills formed in the tower are conveyed to the rotary drum predryer, dryer and cooler, respectively. The predryer and dryer use heated air flowing countercurrent to the product flow to remove moisture from the prills. The cooler uses chilled air to reduce prill temperature.

The prills are then screened. Offsize prills are dissolved and recycled to the vacuum evaporator; product sized prills are coated and either bagged or bulk loaded.

A.3.2 Emission Control Equipment

The emission control equipment used at Plant C consists of a condenser for neutralizer overheads, tray scrubbers for the predryer, dryer and cooler, and scrubbers to control emissions from bagging operations. Emissions from the prill tower, evaporator, screening, coating and conveying equipment are all exhausted to the atmosphere uncontrolled.

The exhausts from the predryer and dryer are sent to a common Sly tray scrubber. Cooler emissions are controlled by a second Sly tray scrubber. The exhausts from both tray scrubbers are ducted to a single discharge stack.

A.3.3 Facilities Tested

Only the outlets (scrubber inlets) from the predryer, dryer and cooler were tested. These facilities were tested to determine mass emissions and particle size distributions. The results of the emission tests are presented in Tables A-12a through A-14b. Particle size results are presented in Figures A-3 through A-5.

A.3.3.1 Testing Problems

Most of the test runs were discontinuous due to excessive loading of dust particles. This excessive amount of dust was found to produce material accumulation of up to 2 inches in the bottom sections of some of the test ducts. The heavy loading of large particles caused plugging of probe nozzles and pitot tubes, making the sampling extremely difficult and resulting in several shut-downs throughout the three test runs.

During test 2 on the predryer, the glass probe liner separated from the union connector and the prescribed leak check conducted after completion of the run failed. For test 3 on the predryer one of the glassware connectors broke. The connector was replaced and the run was resumed.

During the testing of the dryer, several glassware connectors broke. When this occurred, the sampling was stopped and the connector was replaced.

A.3.4 Process Operation During Testing

The process was operating at an average of 107 percent of design capacity during testing.

Several problems were encountered during testing. There was a short process shutdown during the first test run which disrupted testing. Also, it was very difficult to monitor process parameters during the testing. Heavy rains caused the moisture content in the prills to increase. The prills became very sticky, causing the process recording instruments to plug up.

TABLE A-12a. PLANT C: SUMMARY OF EMISSION TEST RESULTS AT THE PREDRYER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	3/29/79	3/30/79	3/30/79	
Isokinetic (%)	93	92	98	94
Production Rate (Mg/hr)	7.56	8.65	8.06	8.09
Ambient Temp. (K)	292	292	292	292
(%) Relative Humidity	53	53	55	54
Exhaust Characteristics				
Flowrate (dnm^3/min)	245	232	162	213
Temperature (K)	328	334	325	329
Moisture (% vol)	2.24	2.24	2.24	2.24
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	7.94	4.58	6.18	6.22
Emission Rate (kg/hr)	117	63.5	59.9	80.3
Emission Factor (g/kg)	15.5	7.35	7.45	10.1
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	Negative	Negative	1.207	a
Emission Rate (kg/hr)			11.7	
Emission Factor (g/kg)			1.45	

[a] No data presented, negative difference.

TABLE A-12b. PLANT C: SUMMARY OF EMISSION TEST RESULTS AT THE PREDRYER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	3/29/79	3/30/79	3/30/79	
Isokinetic (%)	93	92	98	94
Production Rate Tons/hr	8.33	9.54	8.88	8.92
Ambient Temp. °F	65.5	66	66	65.8
(%) Relative Humidity	53	53	55	54
Exhaust Characteristics				
Flowrate (dscfm)	8661	8188	5703	7517
Temperature (F°)	131	142	126	133
Moisture (% vol)	2.24	2.24	2.24	2.24
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	3.47	2.00	2.70	2.72
Emission Rate (lb/hr)	258	140	132	177
Emission Factor (lb/ton)	31.0	14.7	14.9	20.2
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	Negative	Negative	.527	[a]
Emission Rate (lb/hr)			25.8	
Emission Factor (lb/ton)			2.90	

[a] No data presented, negative difference.

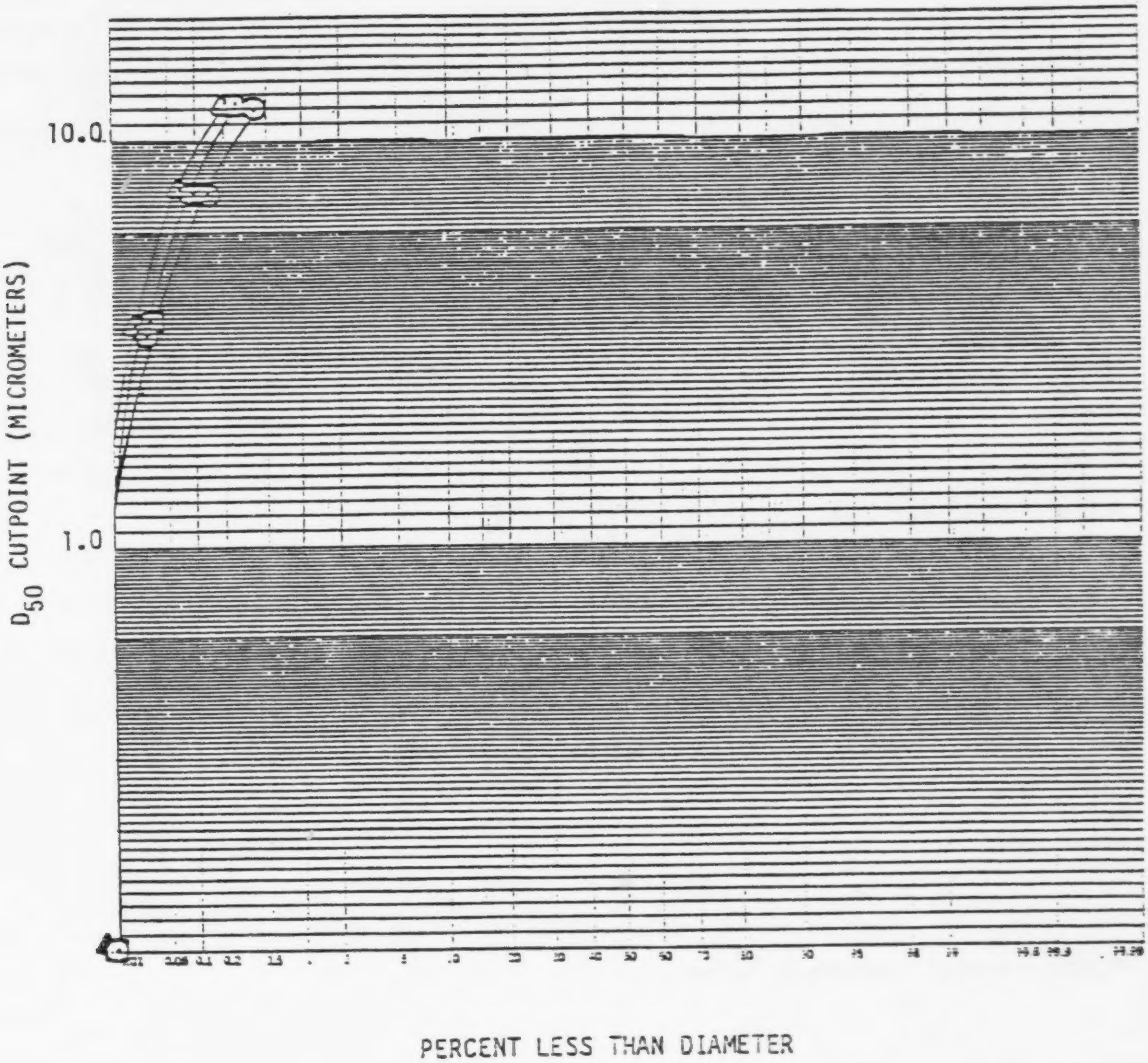

Figure A-3. Plant C: Particle size results at the predryer outlet.

TABLE A-13a. PLANT C: SUMMARY OF EMISSION TEST RESULTS AT THE DRYER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	3/29/79	3/30/79	3/30/79	
Isokinetic (%)	100	101	97	99
Production Rate (Mg/hr)	7.56	8.65	8.06	8.09
Ambient Temp. (K)	292	292	292	292
(%) Relative Humidity	53	50	51	54
Exhaust Characteristics				
Flowrate (dnm^3/min)	167	140	257	188
Temperature (K)	337	345	339	341
Moisture (% Vol.)	2.24	2.24	2.24	2.24
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	9.61	19.2	1.51	10.1
Emission Rate (kg/hr)	96.1	161	23.3	93.4
Emission Factor (g/kg)	12.7	18.7	2.90	11.4
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	negative	3.298	0.401	[a]
Emission Rate (kg/hr)		27.76	6.17	
Emission Factor (g/kg)		3.205	0.765	

[a] No data presented, negative difference.

TABLE A-13b. PLANT C: SUMMARY OF EMISSION TEST RESULTS AT THE DRYER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	3/29/79	3/30/79	3/30/79	
Isokinetic (%)	100	101	97	99
Production Rate Tons/hr	8.33	9.54	8.88	8.92
Ambient Temp. °F	65.5	66	66	65.8
(%) Relative Humidity	53	53	55	54
Exhaust Characteristics				
Flowrate (dscfm)	5888	4957	9060	6635
Temperature (F°)	148	162	151	154
Moisture (% vol)	2.24	2.24	2.24	2.24
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	4.20	8.37	0.661	4.41
Emission Rate (lb/hr)	212	356	51.4	206
Emission Factor (lb/ton)	25.4	37.3	5.79	22.8
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	negative	1.44	0.175	[a]
Emission Rate (lb/hr)		67.2	13.6	
Emission Factor (lb/ton)		64.1	1.53	

[a] No data presented, negative difference.

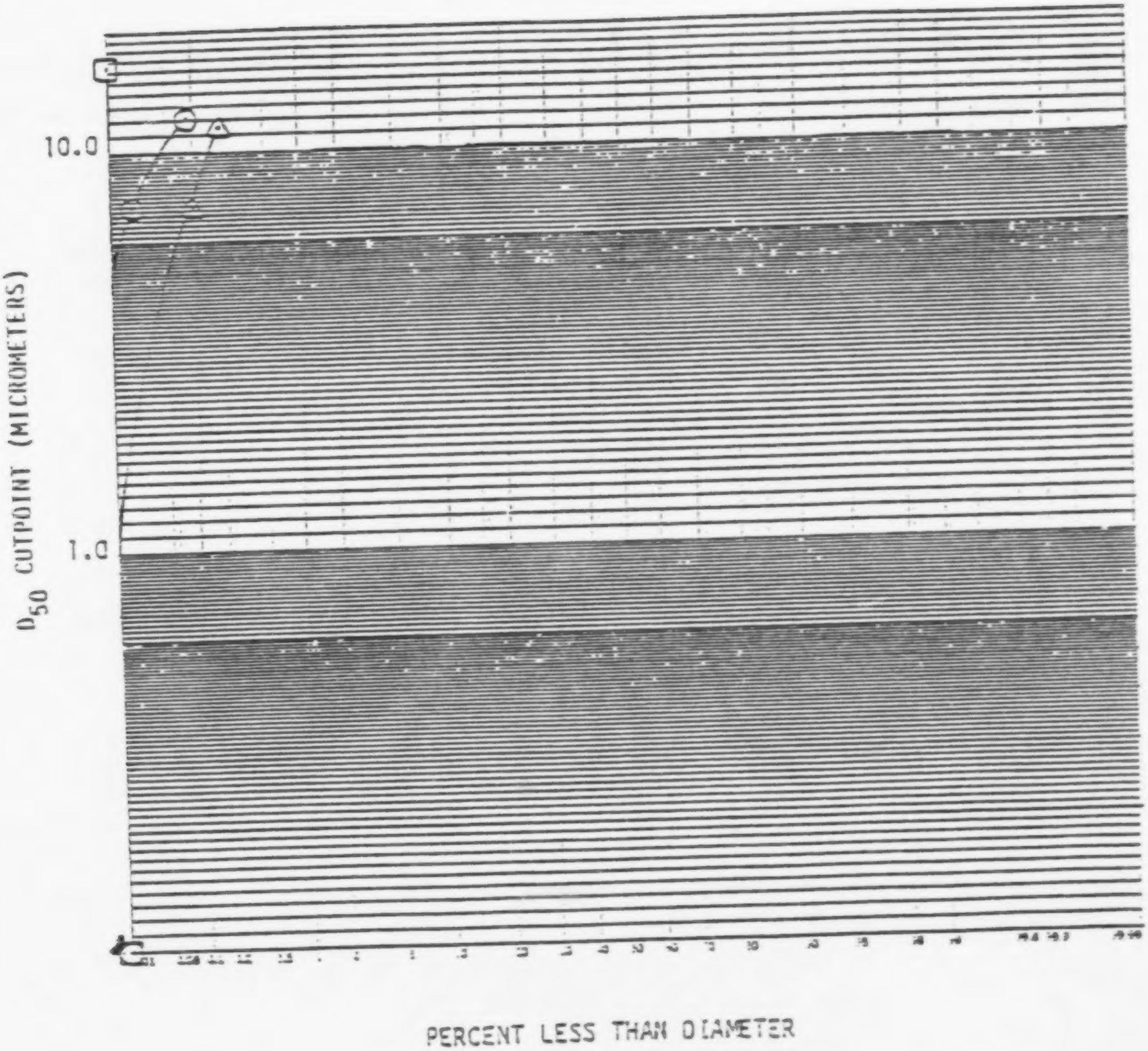

Figure A-4. Plant C: Particle size results at the dryer outlet.

TABLE A-14a. PLANT C: SUMMARY OF EMISSION TEST RESULTS AT THE COOLER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	3/29/79	3/30/79	3/30/79	
Isokinetic (%)	104	102	100	102
Production Rate (Mg/hr)	7.56	8.65	8.06	8.09
Ambient Temp. (K)	292	292	292	292
(%) Relative Humidity	53	50	55	53
Exhaust Characteristics				
Flowrate (dnm^3/min)	217	266	249	244
Temperature (K)	323	322	319	321
Moisture (% Vol.)	2.24	2.24	2.24	2.24
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	8.74	9.04	3.36	7.05
Emission Rate (kg/hr)	109	142	46.7	99.3
Emission Factor (g/kg)	14.5	16.5	5.80	12.3
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	negative	1.088	2.473	a
Emission Rate (kg/hr)		17.15	36.29	
Emission Factor (g/kg)		1.98	4.51	

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[a] No data presented, negative difference.

TABLE A-14b. PLANT C: SUMMARY OF EMISSION TEST RESULTS AT THE COOLER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	3/29/79	3/30/79	3/30/79	
Isokinetic (%)	10.4	102	100	102
Production Rate Tons/hr	8.33	9.54	8.88	8.92
Ambient Temp. °F	65.5	67	66	66.2
(%) Relative Humidity	53	50	55	53
Exhaust Characteristics				
Flowrate (dscfm)	7359	9268	8666	8431
Temperature (F°)	122	121	115	119
Moisture (% Vol.)	2.24	2.24	2.24	2.24
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	3.82	3.95	1.47	3.08
Emission Rate (lb/hr)	241	314	109	219
Emission Factor (lb/ton)	28.9	32.9	11.6	24.5
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	negative	0.475	1.08	[a]
Emission Rate (lb/hr)		37.8	80.0	
Emission Factor (lb/ton)		3.96	9.01	

[a] No data presented, negative difference.

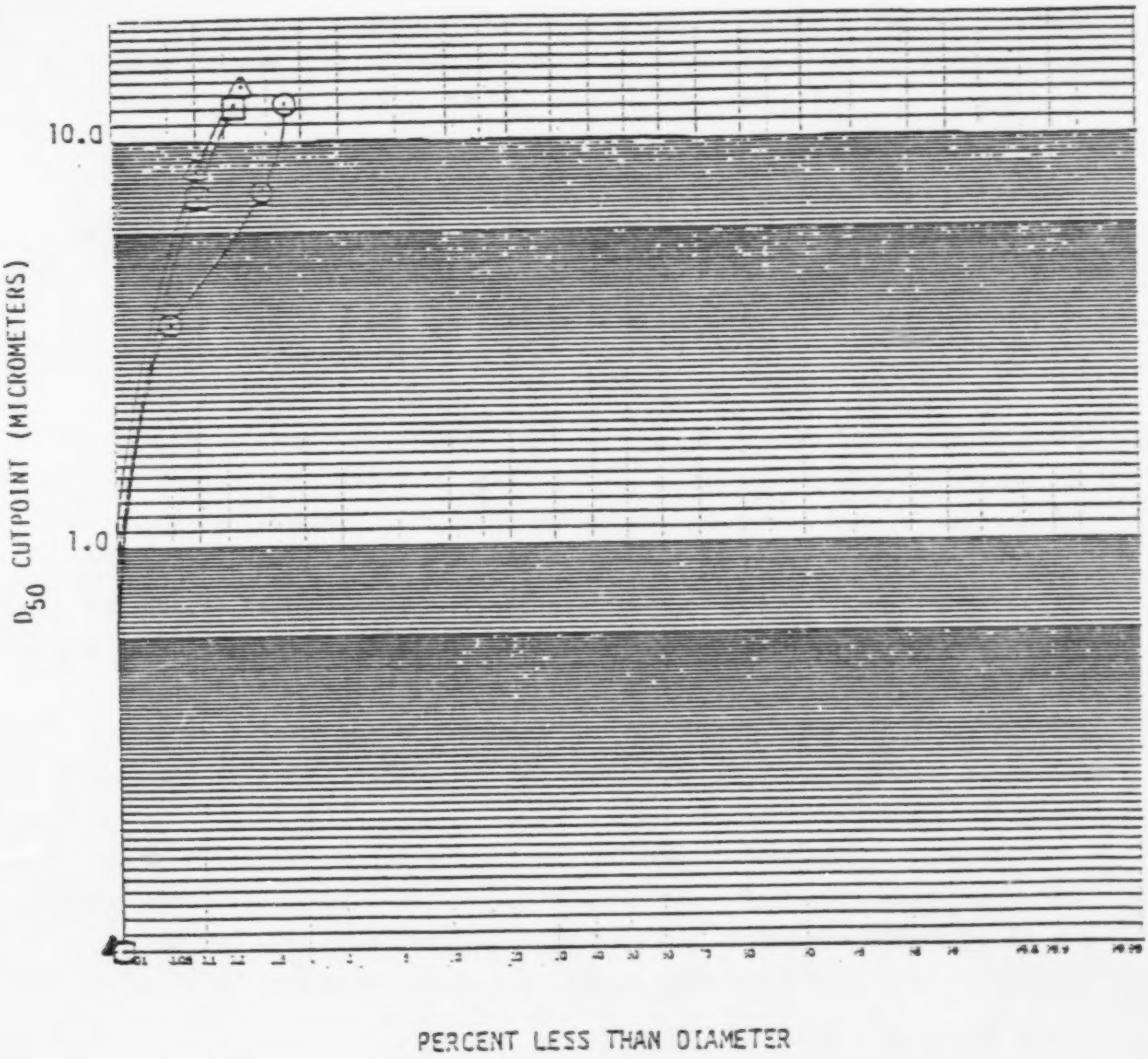

Figure A-5. Plant C: Particle size results at the cooler outlet.

A.4 Plant D[4]

A.4.1 Process Overview

Plant D produces granulated ammonium nitrate using a pan granulator. This plant has a design production rate of 363 Mg/day (400 TPD).

Approximately 90 percent ammonium nitrate solution is produced in a two-stage neutralizer; consequently, less concentration is required. The 90 percent ammonium nitrate solution from the neutralizer is combined with recycled scrubber liquor and fed to an air swept falling film evaporator, where it is concentrated to an essentially anhydrous ammonium nitrate melt.

After concentration, an additive is injected into the melt. The purpose of the additive is to surround the individual crystals formed during the granulation process, which allows for expansion and contraction through the various phase changes, while preventing granule disintegration.

The ammonium nitrate melt is sprayed onto a bed of seed material in the pan granulator. All of the solid product leaving the pan granulator enters a rotary drum precooler. Chilled air is used to cool the granules. The cooled granules exiting the precooler are sent through an enclosed chain mill lump breaker and delivered by bucket to the recycle screen. Undersize granules are recycled to the pan granulator; oversize granules are crushed and then recycled.

Correctly sized product leaving the recycle screen is sent through the rotary drum product cooler. In the cooler, heat-tempered, refrigerated air flows countercurrent to the product flow. Granules leaving the cooler are once again screened, coated, and either bagged or bulk loaded.

A.4.2 Emission Control Equipment

The emission control equipment used at Plant D consists of an HV Brinks unit on the first stage neutralizer, a Sly scrubber on the second stage neutralizer, a variable-throat venturi scrubber on the evaporator and pan granulator, a Buffalo Forge baffle type scrubber on the precooler/crusher area, and two wet cyclones on the cooler. Exhausts from coating and bagging operation are uncontrolled.

The HV Brinks unit on the first stage neutralizer is an integral part of the vessel. Mist removed by Teflon elements is returned directly to the neutralizer.

The off-gas stream from the second stage neutralizer is controlled by a Sly scrubber. The exhaust also passes through a mist eliminator located at the exit point of the vent stack, before being discharged to the atmosphere.

Both evaporator and pan granulator exhausts are controlled by a single, adjustable-throat venturi scrubber. After passing through the venturi, the air stream is sent through a cyclonic droplet separator.

A Buffalo Forge baffle-type scrubber controls emissions from the precooler and crusher area. A dust pick-up on the bucket elevator also exhausts emissions through this scrubber. The initial recycle screen, the crusher screen, the crusher, and transfer points are all exhausted through this scrubber.

The exhausts from the cooler pass through two wet cyclones in parallel before being discharged to the atmosphere.

A.4.3 Facilities Tested

The facilities tested at Plant D are listed below:

Evaporator Outlet
Combined Evaporator-Pan Granulator
Venturi Scrubber Inlet and Outlet
Precooler Outlet
Chain Mill (Crusher) Outlet
Combined Precooler - Chain Mill Baffle Scrubber Outlet
Cooler outlet

All facilities were tested for ammonium nitrate (AN) particulate and ammonia mass emissions. Opacity was observed from the scrubber discharge stacks. Particle size measurements were performed at some of the scrubber inlets, using an Anderson Cascade Impactor. A discussion of the testing at each facility follows. Any problems encountered during the testing are also discussed in the appropriate sections.

A.4.3.1 Evaporator Outlet

The evaporator outlet was tested only for mass emissions. The results of the testing are presented in Tables A-15a and A-15b. While sampling at this point the operator had problems maintaining a constant orifice pressure differential, resulting in high isokinetic sampling ratios for the second and third runs.

A.4.3.2 Combined Evaporator - Pan Granulator Venturi Scrubber Inlet and Outlet

Results of the three mass emission tests are presented in Tables A-16a and A-16b. Visible emissions from the venturi scrubber discharge stack were monitored and are presented in Table A-17.

Also, mass emissions from the pan granulator outlet were determined by taking the difference of the emissions obtained at the venturi scrubber inlet and the emissions from the evaporator outlet. The results of these calculations are presented in Tables A-18a and A-18b.

While sampling at the combined evaporator - pan granulator inlet, the velocity pitot tubes became clogged several times, requiring the use of velocity pressure data obtained from the initial velocity traverse for determination of orifice pressure drops. The fluctuating moisture content of the flue gas, in addition to the other problems encountered, caused the isokinetic sampling ratio to vary during the sampling run. Also, cyclonic flow patterns were suspected at the combined evaporator - pan granulator inlet location, resulting in measured volumetric flow rates ten to fifteen percent lower than actual volumetric flow rates. Since emissions calculations are based on volumetric flow rates, these are also believed to be low by ten to fifteen percent. Consequently, the efficiency calculations would be expected to be less than the actual efficiency.

A.4.3.3 Precooler Outlet

Precooler outlet mass emission test results are presented in Tables A-19a and A-19b. Particle size was also measured at the precooler outlet. Results of the three particle size tests are presented in

Figure A-6. There were no excess ammonia emissions measured at this outlet; there were more nitrate ions present than ammonia in the sample.

A.4.3.4 Chain Mill (Crusher) Outlet

Results of mass emission tests at the chain mill outlet are presented in Tables A-20a and A-20b. This is the only test performed at this point.

A.4.3.5 Combined Precooler - Chain Mill Baffle Scrubber Inlet and Outlet

The results of the mass emission tests on the Buffalo Forge Baffle Scrubber are presented in Tables A-21a and A-21b. Mass emissions from the precooler and chain mill were summed to provide the scrubber inlet values reported in this table. Visible emissions from the scrubber discharge stack were monitored and are reported in Table A-22.

A.4.3.6 Cooler Outlet

The results of the mass emissions tests at the cooler outlet are presented in Tables A-23a and A-23b. The particle size was also tested at this outlet and is presented in Figure A-7.

There was no excess ammonia measured at this outlet; more nitrate ions were present in the sample than ammonia.

A.4.4 Process Operation During Testing

The process was operating at 80 to 91 percent of design capacity during testing. No abnormalities in process operation were noted during the testing.

TABLE A-15a. PLANT D: SUMMARY OF EMISSION TEST RESULTS
AT THE EVAPORATOR OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	11/7/78	11/8/78	11/8/78	
Isokinetic (%)	104	122	112	113
Production Rate (Mg/hr)	13.34	13.34	13.79	13.52
Ambient Temp. (K)	299	296	303	299
(%) Relative Humidity	25	34	21	27
Exhaust Characteristics				
Flowrate (dnm^3/min)	39.71	37.38	29.66	35.57
Temperature (K)	365	369	374	369
Moisture (% Vol.)	55.2	57.9	59.8	57.6
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	0.2013	0.1898	0.2237	0.2050
Emission Rate (kg/hr)	0.4808	0.4264	0.3992	0.4355
Emission Factor (g/kg)	0.036	0.032	0.029	0.0325
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	0.4033	0.4216	0.4349	0.4200
Emission Rate (kg/hr)	0.9616	0.9480	0.7757	0.8936
Emission Factor (g/kg)	0.072	0.071	0.056	0.0665

TABLE A-15b. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE EVAPORATOR OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	11/7/78	11/8/78	11/8/78	
Isokinetic (%)	104	122	112	113
Production Rate Tons/hr	14.7	14.7	15.2	14.9
Ambient Temp. °F	78	74	86	79
(%) Relative Humidity	25	34	21	27
Exhaust Characteristics				
Flowrate (dscfm)	1403	1321	1048	1257
Temperature (F°)	198	205	213	205
Moisture (% Vol.)	55.2	57.9	59.8	57.6
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	0.0879	0.0829	0.0977	0.0895
Emission Rate (lb/hr)	1.06	0.94	0.88	0.96
Emission Factor (lb/ton)	0.072	0.064	0.058	0.065
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	0.1761	0.1841	0.1899	0.1834
Emission Rate (lb/hr)	2.12	2.09	1.71	1.97
Emission Factor (lb/ton)	0.144	0.142	0.112	0.133

TABLE A-16a. PLANT D: SUMMARY OF EMISSION TEST RESULTS FOR THE EVAPORATOR AND PAN GRANULATOR SCRUBBER (METRIC)

Test No.		1	2	3	Ave.
General Data					
Date		11/7/78	11/8/78	11/8/78	
Isokinetic (%) In/Out		78/101	114/103	101/101	98/102
Production Rate (Mg/hr)		13.3	13.3	13.8	13.5
Ambient Temp. (K)		299	296	303	299
(%) Relative Humidity		25	34	21	27
Exhaust Characteristics					
Flowrate (dnm^3/min)	inlet:	225*	208*	216*	216*
	outlet:	257	248	261	255
Temperature (K)	inlet:	358	362	363	361
	outlet:	333	333	332	332
Moisture (% Vol.)	inlet:	23.2	27.9	26.8	26.0
	outlet:	19.5	19.5	19.0	19.3
Control Device Characteristics					
Device Type			Venturi Scrubber		
Pressure Drop (kPa)		6.74	6.74	6.64	6.72
Liquor pH (Ave.)		8.1	8.1	7.75	7.98
Ammonium Nitrate Emissions					
Particulate Conc. (g/dnm^3)	inlet:	2.4726	0.9548	0.7717	1.3997
	outlet:	0.0229	0.0201	0.0094	0.0174
Emission Rate (kg/hr)	inlet:	33.34*	11.93*	9.99*	18.42*
	outlet:	0.35	0.30	0.15	0.27
Emission Factor (g/kg)	inlet:	2.501	0.895	0.725	1.374
	outlet:	0.027	0.023	0.011	0.020
Collection Efficiency (%)		98.9	97.5	98.5	98.3
Ammonia Emissions					
Ammonia Conc. (g/dnm^3)	inlet:	0.1786	0.1163	0.1408	0.1452
	outlet:	0.5125	0.3653	0.2631	0.3804
Emission Rate (kg/hr)	inlet:	2.404	1.452	1.824	1.892
	outlet:	7.911	5.443	4.119	5.824
Emission Factor (g/kg)	inlet:	0.181	0.109	0.132	0.141
	outlet:	0.593	0.408	0.299	0.433
Collection Efficiency (%)		negative	negative	negative	negative

*Cyclonic flow patterns suspected, volumetric flows believed to be approximately 10 to 15 percent low.

TABLE A-16b. PLANT D: SUMMARY OF EMISSION TEST RESULTS FOR THE EVAPORATOR AND PAN GRANULATOR SCRUBBER (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		11/7/78	11/8/78	11/8/78	
Isokinetic (%) In/Out		78/101	114/103	101/101	98/102
Production Rate Tons/hr		14.7	14.7	15.2	14.9
Ambient Temp. °F		78	74	86	79
(%) Relative Humidity		25	34	21	27
Exhaust Characteristics					
Flowrate	inlet:	7936*	7355*	7619*	7637*
(dscfm)	outlet:	9089	8773	9214	9025
Temperature	inlet:	186	192	194	191
(F°)	outlet:	140	140	138	139
Moisture (% Vol.)	inlet:	23.2	27.9	26.8	26.0
	outlet:	19.5	19.5	19.0	19.3
Control Device Characteristics					
Device Type			Venturi Scrubber		
Pressure Drop (in W.G.)		27.1	27.1	26.7	27.0
Liquor pH (Ave.)		8.1	8.1	7.75	7.98
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	1.0807	0.4173	0.3373	0.6118
(gr/dscf)	outlet:	0.010	0.0088	0.0041	0.0076
Emission Rate	inlet:	73.51*	26.31*	22.02*	40.61*
(lb/hr)	outlet:	0.78	0.66	0.32	0.59
Emission Factor	inlet:	5.001	1.79	1.449	2.747
(lb/ton)	outlet:	0.053	0.045	0.021	0.040
Collection Efficiency (%)		98.9	97.5	98.5	98.3
Ammonia Emissions					
Ammonia Conc.	inlet:	0.0780	0.0508	0.0615	0.0634
(gr/dscf)	outlet:	0.2238	0.1595	0.1149	0.1661
Emission Rate	inlet:	5.30	3.20	4.02	4.17
(lb/hr)	outlet:	17.44	12.00	9.08	12.84
Emission Factor	inlet:	0.361	0.218	0.264	0.281
(lb/ton)	outlet:	1.186	0.816	0.597	0.866
Collection Efficiency (%)		negative	negative	negative	negative

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*Cyclonic flow patterns suspected, volumetric flows believed to be approximately 10 to 15 percent low.

TABLE A-17. PLANT D: OPACITY READINGS AT THE VENTURI SCRUBBER STACK

TEST NO.	1	2	3	4
GENERAL DATA				
Date	11/7	11/7	11/8	11/8
Time	1110-1310	1600-1700	0915-1115	1345-1530
Steam Dispersion Distance (Ft)	80	68	100	47
SIX MINUTE INTERVAL AVERAGE OPACITY (%)				
1	5	10	8	10
2	5	9.5	11	10
3	7	11	9	10
4	7.5	11	10	10
5	5	8	10	10
6	5	10	10	10
7	5	11.5	9	10
8	6	10.4	10	10
9	5	11.5	10	10
10	6	10	10	9
11	5	-	10	8
12	7	-	10	10
13	5	-	10	10
14	5	-	10	9
15	5	-	10	10
16	5	-	10	10
17	5	-	10	10
18	5	-	12	10*
19	5	-	10	-
20	6	-	10	-

* 3 Minute Interval

TABLE A-18a. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE PAN GRANULATOR OUTLET[a] (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	11/7/78	11/8/78	11/8/78	
Production Rate (Mg/hr)	13.3	13.3	13.8	13.5
Ambient Temp. (K)	299	296	303	299
(%) Relative Humidity	25	34	21	27
Exhaust Characteristics				
Flowrate (dnm^3/min)	185[b]	171[b]	186[b]	181[b]
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	2.962	1.123	0.859	1.648
Emission Rate (kg/hr)	32.86	11.51	9.59	17.99
Emission Factor (g/kg)	2.465	0.863	0.696	1.341
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	0.1301	0.0492	0.0939	0.0911
Emission Rate (kg/hr)	1.442	0.504	1.048	0.998
Emission Factor (g/kg)	0.108	0.038	0.076	0.074

[a] Determined from the difference of the evaporator and combined evaporator-pan granulator data.

[b] Cyclonic flow suspected at the combined inlet.

TABLE A-18b. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE PAN GRANULATOR OUTLET[a] (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	11/7/78	11/8/78	11/8/78	
Production Rate Tons/hr	14.7	14.7	15.2	14.9
Ambient Temp. °F	78	74	86	79
(%) Relative Humidity	25	34	21	27
Exhaust Characteristics				
Flowrate (dscfm)	6533[b]	6034[b]	6571[b]	6379[b]
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	1.2934	0.4904	0.3752	0.7197
Emission Rate (lb/hr)	72.45	25.37	21.14	39.65
Emission Factor (lb/ton)	4.929	1.726	1.391	2.682
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	0.0568	0.0215	0.0410	0.0398
Emission Rate (lb/hr)	3.18	1.11	2.31	2.20
Emission Factor (lb/ton)	0.216	0.076	0.152	0.148

[a] Determined from the difference of the evaporator and combined evaporator - pan granulator data.

[b] Cyclonic flow suspected at the combined inlet.

TABLE A-19a. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE PRECOOLER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	11/9/78	11/10/78	11/10/78	
Isokinetic (%)	100	101	98	100
Production Rate (Mg/hr)	13.52	13.36	13.25	13.36
Ambient Temp. (K)	295	292	297	295
(%) Relative Humidity	26	57	52	45
Exhaust Characteristics				
Flowrate (dnm^3/min)	611[a]	699[a]	811[a]	707[a]
Temperature (K)	366	356	356	360
Moisture (% Vol.)	2.0	2.0	2.0	2.0
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	4.890	5.985	5.956	5.611
Emission Rate (kg/hr)	179.34	251.14	289.97	240.15
Emission Factor (g/kg)	13.267	18.832	21.893	17.997
Ammonia Emissions[b]				

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[a] Suspected to be low due to only one traverse being performed.

[b] Ammonia emissions are all negative, more nitrate ions than ammonia present.

TABLE A-19b. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE PRECOOLER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	11/9/78	11/10/78	11/10/78	
Isokinetic (%)	100	101	98	100
Production Rate Tons/hr	14.9	14.7	14.6	14.7
Ambient Temp. °F	72	66	75	71
(%) Relative Humidity	26	57	52	45
Exhaust Characteristics				
Flowrate (dscfm)	21593[a]	24707	28666	24989
Temperature (F°)	200	181	182	188
Moisture (% Vol.)	2.0	2.0	2.0	2.0
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	2.1355	2.6136	2.6009	2.450
Emission Rate (lb/hr)	395.36	553.65	639.26	529.42
Emission Factor (lb/ton)	26.534	37.663	43.785	35.994
Ammonia Emissions[b]				

[a] Suspected to be low due to only one traverse being performed during the tests.

[b] Ammonia emissions are all negative, more nitrate ions than ammonia present.

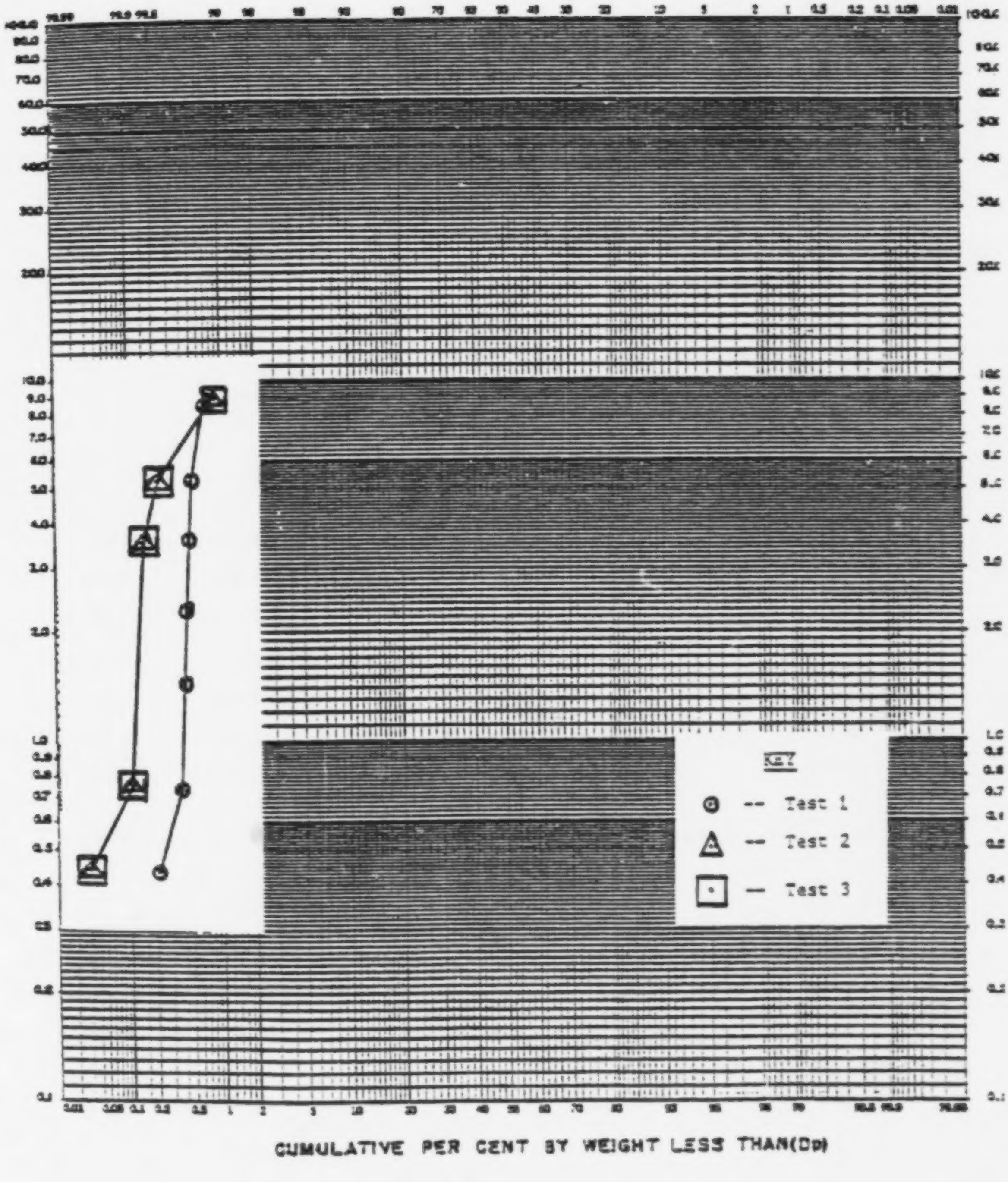

Figure A-6. Plant D: Particle size results at the precooler scrubber inlet.

TABLE A-20a. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE CHAIN MILL OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	11/9/78	11/10/78	11/10/78	
Isokinetic (%)	101	101	105	102
Production Rate (Mg/hr)	13.5	13.3	13.2	13.3
Ambient Temp. (K)	295	292	297	295
(%) Relative Humidity	26	57	52	45
Exhaust Characteristics				
Flowrate (dnm^3/min)	47.29	39.59	39.71	42.20
Temperature (K)	301	300	307	302
Moisture (% Vol.)	0.8	1.6	4.4	2.2
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	2.244	1.754	2.549	2.182
Emission Rate (kg/hr)	6.369	4.169	6.074	5.539
Emission Factor (g/kg)	0.471	0.313	0.459	0.414
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	negative	0.0421	0.0094	0.0172
Emission Rate (kg/hr)		0.0998	0.0227	0.0408
Emission Factor (g/kg)		0.0075	0.0015	0.003

TABLE A-20b. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE CHAIN MILL OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	11/9/78	11/10/78	11/10/78	
Isokinetic (%)	101	101	105	102
Production Rate Tons/hr	14.9	14.7	14.6	14.7
Ambient Temp. °F	72	66	75	71
(%) Relative Humidity	26	57	52	45
Exhaust Characteristics				
Flowrate (dscfm)	1671	1399	1403	1491
Temperature (F°)	83	81	93	85
Moisture (% Vol.)	0.8	1.6	4.4	2.2
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	0.9801	0.7658	1.1130	0.9530
Emission Rate (lb/hr)	14.04	9.19	13.39	12.21
Emission Factor (lb/ton)	0.942	0.625	0.917	0.828
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	negative	0.0184	0.0041	0.0075
Emission Rate (lb/hr)		0.22	0.05	0.09
Emission Factor (lb/ton)		0.015	0.003	0.006

TABLE A-21a. PLANT D: SUMMARY OF EMISSION TEST RESULTS FOR THE CHAIN MILL AND PRECOOLER SCRUBBER[a] (METRIC)

Test No.		1	2	3	Ave.
General Data					
Date		11/9/78	11/10/78	11/10/78	
Isokinetic (%) Out		102	102	102	102
Production Rate (Mg/hr)		13.5	13.3	13.2	13.3
Ambient Temp. (K)		295	292	297	295
(%) Relative Humidity		26	57	52	45
Exhaust Characteristics					
Flowrate	inlet:	659	739	852	750
(dnm^3/min)	outlet:	733	732	766	744
Temperature (K)	outlet:	317	317	318	318
Moisture (%Vol.)	outlet:	3.4	4.0	4.9	4.1
Control Device Characteristics					
Device Type		Buffalo Forge Scrubber			
Pressure Drop (kPa)		0.796	1.72	1.69	1.39
Liquor pH (Ave.)		6.3	6.6	6.0	6.3
Ammonium Nitrate Emissions					
Particulate Con.	inlet:	4.6845	5.7397	5.7781	5.4008
(g/dnm^3)	outlet:	0.0247	0.0460	0.0332	0.0345
Emission Rate	inlet:	185.246	254.696	295.325	245.089
(kg/hr)	outlet:	1.084	2.023	1.529	1.547
Emission factor	inlet:	3.705	19.099	22.297	18.367
(g/kg)	outlet:	0.080	0.152	0.116	0.116
Collection Efficiency (%)		99.4	99.2	99.5	99.4
Ammonia Emissions[b]					
Ammonia Conc. (g/dnm^3)	outlet:	0.0087	0.1001	0.1347	0.0811
Emission Rate (kg/hr)	outlet:	0.3810	4.391	6.187	3.652
Emission Factor (g/kg)	outlet:	0.028	0.330	0.468	0.275

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[a] Inlet data is based on the combination of the chain mill and precooler data.

[b] Ammonia emissions from the precooler are all negative.

TABLE A-21b. PLANT D: SUMMARY OF EMISSION TEST RESULTS FOR THE CHAIN MILL AND PRECOOLER SCRUBBER[a] (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		11/9/78	11/10/78	11/10/78	
Isokinetic (%) Out		102	102	102	102
Production Rate Tons/hr		14.9	14.7	14.6	14.7
Ambient Temp. °F		72	66	75	71
(%) Relative Humidity		26	57	52	45
Exhaust Characteristics					
Flowrate	inlet:	23,264	26,106	30,069	26,480
(dscfm)	outlet:	25,866	25,843	27,062	26,257
Temperature (F°)	outlet:	112	112	113	112
Moisture(% Vol.)	outlet	3.4	4.0	4.9	4.1
Control Device Characteristics					
Device Type			Buffalo Forge Scrubber		
Pressure Drop (in W.G.)		3.2	6.9	6.8	5.6
Liquor pH (Ave.)		6.3	6.6	6.0	6.3
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	2.0474	2.5086	2.5254	2.3605
(gr/dscf)	outlet:	0.0108	0.0202	0.0145	0.0152
Emission Rate	inlet:	408.39	561.50	651.07	540.32
(lb/hr)	outlet:	2.4	4.47	3.37	3.41
Emission Factor	inlet:	27.409	38.197	44.594	36.733
(lb/ton)	outlet:	0.161	0.304	0.231	0.232
Collection Efficiency (%)		99.4	99.2	99.5	99.4
Ammonia Emissions[b]					
Ammonia Conc. (gr/dscf)	outlet:	0.0038	0.0437	0.0588	0.0354
Emission Rate (lb/hr)	outlet:	0.84	9.68	13.64	8.05
Emission Factor (lb/ton)	outlet:	0.056	0.659	0.935	0.550

[a] Inlet data is based on the combination of the chain mill and precooler data.

[b] Ammonia emissions from the precooler are all negative.

TABLE A-22. PLANT D: OPACITY READINGS AT THE BUFFALO FORGE SCRUBBER STACK

TEST NO.	1	2	3
GENERAL DATA			
Date	11/10	11/10	11/10
Time	0947-1047	1130-1430	1430-1630
SIX MINUTE INTERVAL AVERAGE OPACITY (%)			
1	10	11	10
2	9	11	10
3	10	10	11
4	11	10	11
5	10	10	10
6	10	10	10
7	10	10	10
8	10	11	10
9	10	10	10
10	9	10	10
11	-	11	9
12	-	10	11
13	-	10	10
14	-	11	8
15	-	10	9
16	-	10	7.5
17	-	11	8.5
18	-	10	7
19	-	10	6.5
20	-	10	7
21	-	10	-
22	-	10	-
23	-	10	-
24	-	10	-
25	-	10	-
26	-	10	-
27	-	10	-
38	-	10	-
29	-	10	-
30	-	10	-

TABLE A-23a. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE COOLER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	11/3/78	11/4/78	11/4/78	
Isokinetic (%)	96	101	101	99
Production Rate (Mg/hr)	13.3	12.8	13.3	13.2
Ambient Temp. (K)	302	295	302	300
(%) Relative Humidity	36	49	34	40
Exhaust Characteristics				
Flowrate (dnm^3/min)	351	347	349	350
Temperature (K)	351	349	352	350
Moisture (% Vol.)	1.3	1.3	1.2	1.3
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	0.106	0.205	0.115	0.153
Emission Rate (kg/hr)	2.227	4.264	2.400	3.216
Emission Factor (g/kg)	0.167	0.333	0.180	0.246
Ammonia Emissions[a]				

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[a] Ammonia emissions are all negative, more nitrate than ammonia ions present.

TABLE A-23b. PLANT D: SUMMARY OF EMISSION TEST RESULTS AT THE COOLER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	11/3/78	11/4/78	11/4/78	
Isokinetic (%)	96	101	101	99
Production Rate Tons/hr	14.7	14.1	14.7	14.5
Ambient Temp. °F	85	72	84	80
(%) Relative Humidity	36	49	34	40
Exhaust Characteristics				
Flowrate (dscfm)	12,396	12,249	12,348	12,382
Temperature (F°)	173	168	174	171
Moisture (% Vol.)	1.3	1.3	1.2	1.3
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	0.0463	0.0897	0.050	0.0669
Emission Rate (lb/hr)	4.91	9.40	5.29	7.09
Emission Factor (lb/ton)	0.334	0.666	0.360	0.492
Ammonia Emissions[a]				

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[a] Ammonia emissions are all negative, more nitrate than ammonia ions present.

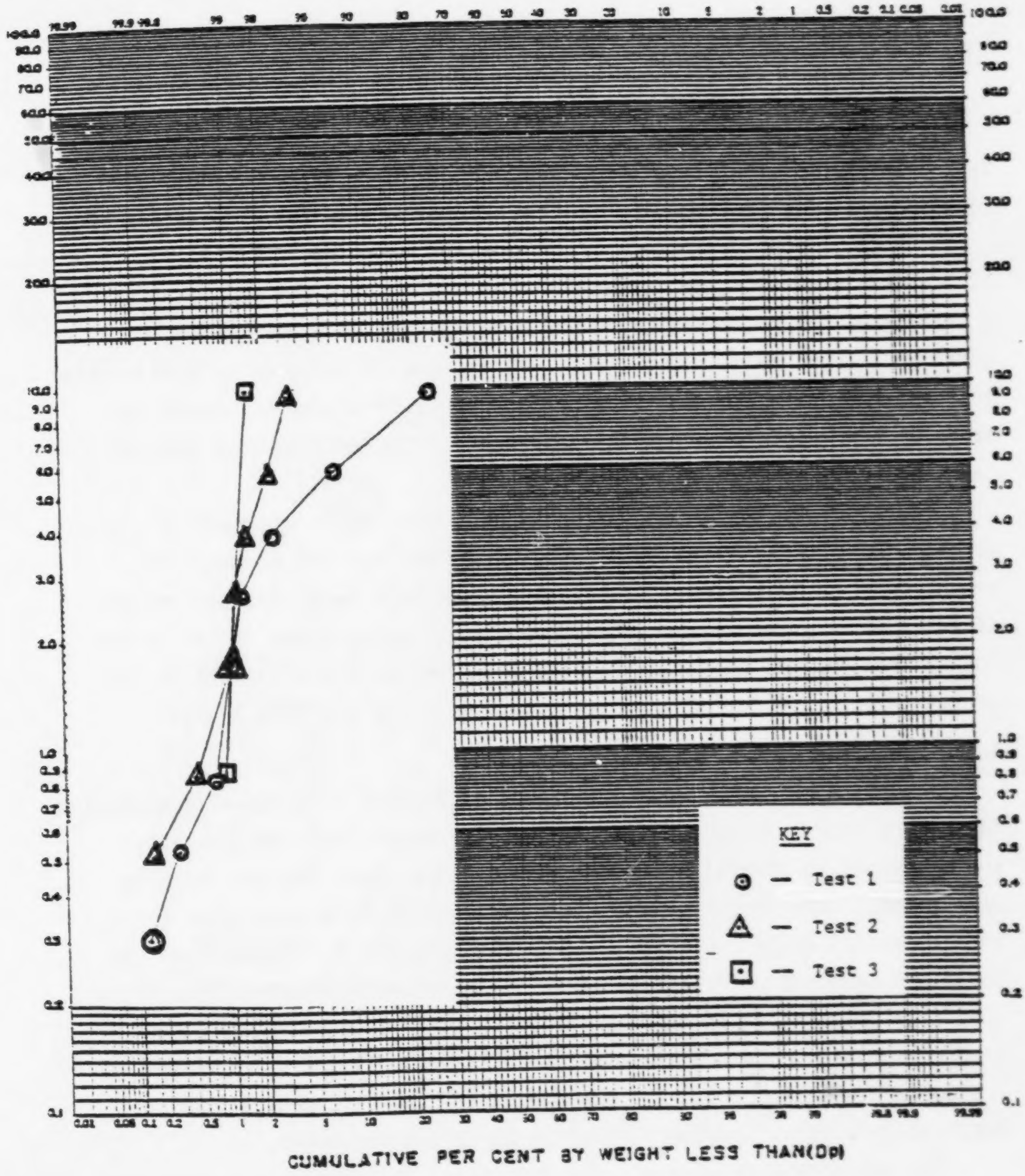

Figure A-7. Plant D: Particle size results at the cooler scrubber inlet.

A.5 Plant E[5]

A.5.1 Process Description

Plant E produces ammonium nitrate granules in rotary drum granulators. This plant has a design production rate of 435 Mg/day (480 TPD) of ammonium nitrate.

The 85 percent ammonium nitrate solution produced in the neutralizer is combined with recycled scrubber liquor and the product from cleanup operations. This combined stream is concentrated to a 99+ percent ammonium nitrate melt in two steps. First, the AN solution is concentrated in a flash evaporator, then this product is split and sent through two parallel air swept falling film evaporators. The melt is then sprayed into the granulators.

There are two rotary drum granulators; each has its own set of screens and product cooler. Oversize particles from the screens are crushed and returned to the granulator. Undersize particles are returned directly to the granulator. The product size granules are cooled in the rotary drum coolers with refrigerated air flowing countercurrent to the granule flow. The cooled granules are then coated and bulk loaded.

A.5.2 Emission Control Equipment

The emission control equipment used at Plant E consists of a condenser for neutralizer overheads, wet scrubbers for granulators and coolers, and baghouses to control emissions from coating, handling and shipping operations. Emissions from the air swept falling film evaporator and the hammermill are directed to the granulator scrubber. Emissions from the flash evaporator are exhausted to the atmosphere uncontrolled.

Each granulator has two wet scrubbers controlling exhausts, and each cooler has one scrubber. The exhausts from all the wet scubbers are ducted to a common stack. The condensate from the neutralizer overhead is used as scrubber liquor in these wet scrubbers.

The wet scrubbers used are Joy Turbulaire medium pressure drop wet impingement scrubbers, referred to as "Doyle" units. Air entering the scrubbers enters a cone-shaped downcomer, causing it to impinge on a liquor pool. Scrubber liquor is sprayed on the entering airstream in each downcomer. The exhaust then passes over and under a set of baffles and exits the scrubber.

A.5.3 Facilities Tested

Only one source was tested at Plant E, the No. 1 cooler scrubber. The inlet and outlet of this scrubber were tested for ammonium nitrate particulate and ammonia emissions. The scrubber inlet was also tested to determine particle size with an Anderson Cascade Impactor. The results of the emission tests are presented in Tables A-24a and A-24b, and the particle size results are presented in Figure A-8.

A.5.3.1 Testing Problems

Most of the test runs were discontinuous due to excessive particulate loading at the scrubber inlet sampling location. Data from test 3 are believed to be nontypical of the sampled source, and are not represented in the average data. The ammonium nitrate concentration at the scrubber outlet was found to be greater than the concentration at the inlet during test 3. During train clean-up a residue was noted on the inside of the probe. This residue was not present in tests 1 and 2.

A.5.4 Process Operation During Testing

The process was operating at 62 to 66 percent of design capacity during the testing. No major irregularities in process operation were noted during testing, although the cooler outlet air temperature and the cooler inlet and outlet solids temperature varied considerably during the individual test periods.

TABLE A-24a. PLANT E: SUMMARY OF EMISSION TEST RESULTS FOR THE COOLER SCRUBBER (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	11/15/78	11/15/78	*11/16/78	*
Isokinetic (%) In/Out	109/106	105/105	102/104	105/106
Production Rate (Mg/hr)	11.52	11.26	11.86	11.38
Ambient Temp. (K)	279	281	278	279
(%) Relative Humidity	62	54	69	62
Exhaust Characteristics				
Flowrate inlet:	428	397	424	413
(dnm^3/min) outlet:	438	455	483	459
Temperature inlet:	325	329	319	327
(K) outlet:	307	308	308	307
Moisture(% Vol.) inlet:	1.1	1.5	0.7	1.3
outlet:	3.4	3.5	3.1	3.5
Control Device Characteristics				
Device Type	Doyle wet impingement scrubber			
Pressure Drop (kPa)	3.28	3.28	3.23	3.27
Liquor pH (Ave.)	3.7	4.5	4.3	4.2
Liquor Conc. (%) Ave.	23	26	26	25
Ammonium Nitrate Emissions				
Particulate Conc. inlet:	3.86	4.09	0.441	3.98
(g/dnm^3) outlet:	0.014	0.135	2.14	0.014
Emission Rate inlet:	99.17	97.55	11.23	98.36
(kg/hr) outlet:	0.38	0.37	62.10	0.38
Emission factor inlet:	8.63	8.65	0.945	8.65
(g/kg) outlet:	0.033	0.33	5.25	0.033
Collection Efficiency (%)	99.6	99.6	Negative	99.6
Ammonia Emissions				
Ammonia Conc. inlet:	0.5526	0.5279	1.3481	0.5402
(g/dnm^3) outlet:	0.0080	0.0066	0.0373	0.0073
Emission Rate inlet:	14.20	12.57	34.25	13.38
(kg/hr) outlet:	0.209	0.181	1.08	0.195
Emission Factor inlet	1.235	1.115	2.88	1.175
(g/kg) outlet:	0.018	0.016	0.091	0.017
Collection Efficiency (%)	98.5	98.6	96.8	98.6

*Run 3 Questionable, not used in average.

TABLE A-24b. PLANT E: SUMMARY OF EMISSION TEST RESULTS FOR THE COOLER SCRUBBER (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		11/15/78	11/15/78	*11/16/78	*
Isokinetic (%) In/Out		104/106	105/105	102/104	104/105
Production Rate Tons/hr		12.69	12.41	13.07	12.54
Ambient Temp. °F		43	46	41	43
(%) Relative Humidity		62	54	69	62
Exhaust Characteristics					
Flowrate	inlet:	15,111	14,018	14,968	14,600
(dscfm)	outlet:	15,471	16,065	17,044	15,768
Temperature	inlet:	125	133	115	129
(F°)	outlet:	94	95	95	94
Moisture (% Vol.)	inlet:	1.1	1.5	0.7	1.3
	outlet:	3.4	3.5	3.1	3.5
Control Device Characteristics					
Device Type		Doyle wet impingement scrubber			
Pressure Drop (in. W.G.)		13.2	13.2	13.0	13.1
Liquor pH (Ave.)		3.7	4.5	4.3	4.2
Liquor AN Conc. (%) (Ave.)		23	26	26	25
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	1.688	1.790	0.1929	1.739
(gr/dscf)	outlet:	0.0063	0.0059	0.9371	0.0061
Emission Rate	inlet:	218.6	215.0	24.74	216.8
(lb/hr)	outlet:	0.835	0.816	136.9	0.826
Emission Factor	inlet:	17.3	17.3	1.89	17.3
(lb/ton)	outlet:	0.066	0.066	10.5	0.066
Collection Efficiency (%)		99.6	99.6		99.6
Ammonia Emissions					
Ammonia Conc.	inlet:	0.2413	0.2305	0.5887	0.2359
(gr/dscf)	outlet:	0.0035	0.0029	0.0163	0.0032
Emission Rate	inlet	31.3	27.7	75.5	29.5
(lb/hr)	outlet:	0.461	0.399	2.38	0.430
Emission Factor	inlet:	2.47	2.23	5.76	2.35
(lb/ton)	outlet:	0.636	0.032	0.182	0.034
Collection Efficiency		98.5	98.6	96.8	98.6

*Run 3 Questionable, not used in average.

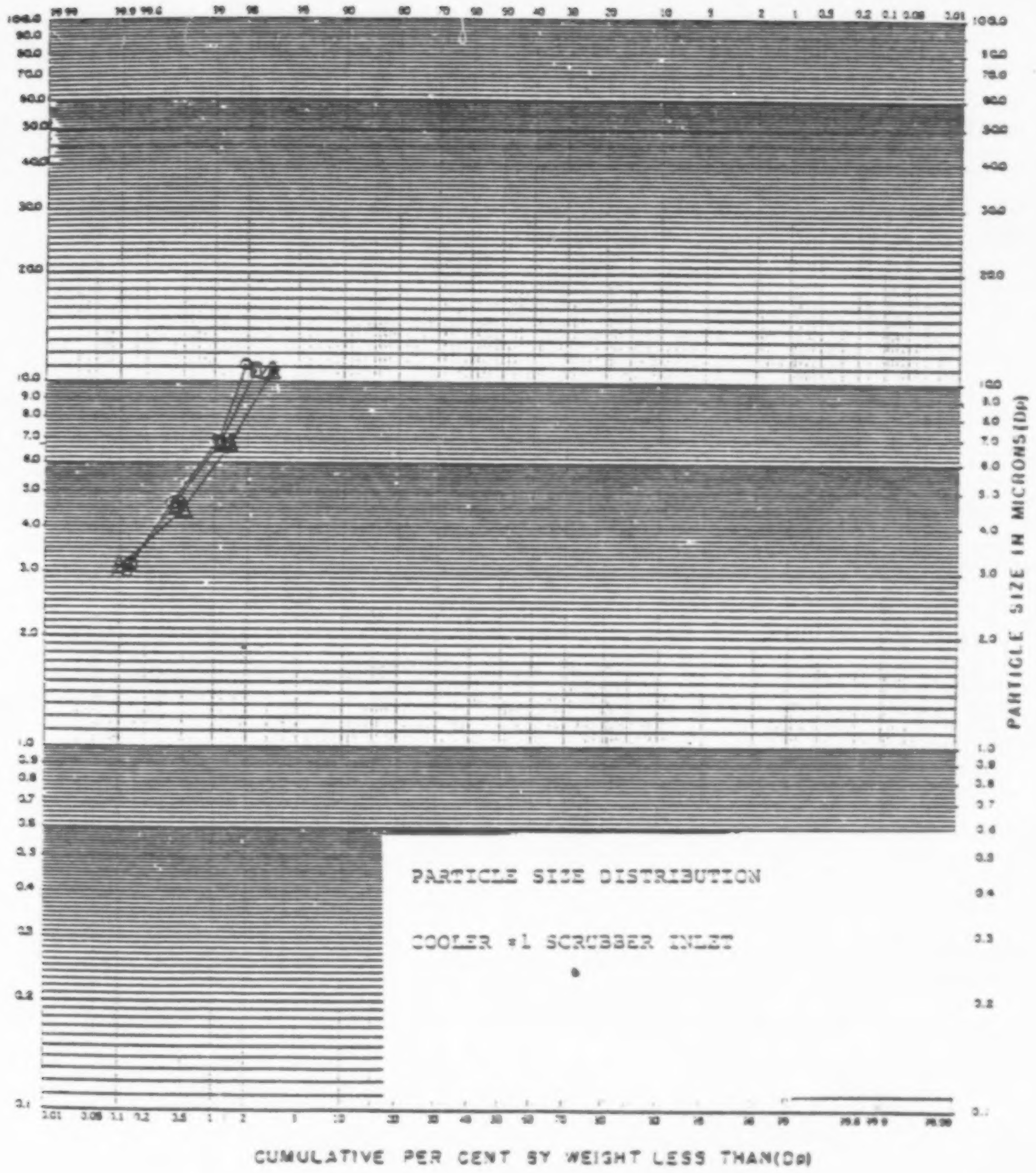

Figure A-8. Plant E: Particle size results at the cooler scrubber inlet.

A.6 Plant Z[6]

A.6.1 Process Description

Plant Z produces both low density and high density ammonium nitrate prills. The plant was designed to produce 726 Mg/day (800 TPD) of prilled ammonium nitrate. Only the emissions from the solids formation and finishing equipment were monitored; therefore, only these solids production facilities are discussed.

The prill tower at Plant Z is designed to produce both high and low density prills. The type of product produced depends upon the concentration of the AN melt used. A 99.8 percent AN melt is used to produce high density prills, and a 96 percent AN melt is used to produce low density prills.

During the testing program low density prills were being produced. For low density prill production, a 96 percent AN melt is delivered from the evaporators to the top of the prill tower. A spinning bucket at the top of the tower receives the melt, where it rotates to force a stream of melt through orifices in the bucket. The melt stream breaks up into discrete droplets as it falls through the tower. Four fans located at the top of the prill tower create an airflow which cools the falling droplets. The prills are conveyed from the bottom of the tower to the finishing train, the predryer, dryer and cooler. First, the low density prills are conveyed to a rotary drum predryer, where moisture is removed from the prills. Finally, a fluidized bed cooler is used to remove nominal amounts of moisture and to cool the prills. Cooled prills are then screened to yield a properly sized product.

Offsize prills are redissolved and recycled to the melt concentration process. Product sized prills are coated in a rotary drum coater with kaolin (clay). A coating is used to prevent the solids from becoming moist and caking. The coated product is then either bulk shipped or bagged.

A.6.2 Emission Control Equipment

The equipment used to control emissions from the prill tower, predryer, dryer, cooler, screens, coater and bagger are discussed below.

Emissions from the prill tower are controlled with a collection device and a Monsanto HE Brinks Mist Eliminator which is located on top of the tower. The tower is equipped with four fans; three of which are located at the top of the tower along the periphery (bypass). The other fan is located at the top of the tower after the mist eliminator, with inlets located within the collection device. The stainless steel collection device is located around the spinning bucket. Since most of the fuming and ammonium nitrate emissions occur as the melt exits the bucket, the collection device captures a large portion of the emissions and ducts this portion to the mist eliminator. The air that does not get ducted to the mist eliminator is discharged through the three bypass stacks.

The Brinks Mist Eliminator contains atomizing sprays and spray catcher elements to remove large particulates and high efficiency elements to remove fine particulates. The liquor for the sprays comes from the evaporator condensate. The liquor is pH adjusted, using nitric acid to maintain the pH near neutral; otherwise, the fiberglass filter elements would corrode. The liquor is recycled through the Brinks until it reaches an AN concentration near 5 percent. The liquor is then recycled to the AN solution formation process.

Emissions from the rotary drum predryer and dryer are combined and ducted to a single Peabody tray scrubber. The fluidized bed cooler uses two inlet air streams to cool the prills. One of these air streams is discharged to a Ducon mechanical impingement scrubber, and the other stream is discharged, uncontrolled, through a vent.

Emissions from the screening operation are ducted to a baghouse fabric filter. Rotary drum coater emissions are also controlled by a baghouse. The clay dust captured by the fabric filter is returned to the clay storage bins for reuse in the coater. Emissions from bagging operations are controlled by fabric filters, too. Captured dust is also returned to the clay storage bins.

A.6.3 Facilities Tested

The facilities tested at Plant Z are listed below:

Low density prill tower scrubber inlet, outlet and bypass
Rotary drum predryer outlet
Rotary drum dryer outlet
Combined predryer-dryer scrubber outlet
Fluidized bed cooler scrubber inlet
Bagging and coating operations

Visible emission observations were performed at all of the scrubber outlets and at the outlets from the coater and bagger. Particle size measurements were performed at all of the scrubber inlets and bypasses. An Anderson High Capacity Stack Sampler was used to determine particle size distributions. A discussion of the testing at each facility including any testing problems that occurred, follows.

A.6.3.1 Low Density Prill Tower Scrubber

The results of the mass emission tests performed on the bypass and the Brinks Mist Eliminator inlet and outlet are presented in Tables A-25a and A-25b. Prill tower emissions are ducted to the Brinks Mist Eliminator through three inlet ducts. Three ducts are also used to bypass the mist eliminator. During each test run, emissions were measured at one inlet, one bypass and the outlet. Velocity traverses were performed at the other two inlets and two bypasses during each test run in order to determine flow rates through these ducts. Estimates of emissions from all the inlets and bypasses during each test run were made by assuming the grain loadings measured in a given inlet or bypass existed in the other two inlets or bypasses.

The opacity readings at the Brinks Mist Eliminator outlet are presented in Table A-26; opacity readings for the scrubber bypass are presented in Table A-27. Particle size results at the scrubber inlet are presented in Figure A-9, particle sizes results for the bypass are presented in Figure A-10. No problems were encountered during testing at this scrubber.

A.6.3.2 Rotary Drum Predryer Outlet

Results of the mass emission tests performed at the predryer outlet are presented in Tables A-28a and A-28b. The results of the particle size tests are presented in Figure A-11.

High grain loadings at this point caused immediate nozzle and pitot tube plugging when the tests were begun. Larger diameter nozzles were then attached to the probes and plugging problems were greatly reduced. However, the sampling train pumps were unable to draw a sufficient flow through these larger nozzles to maintain isokinetic sampling conditions. To compensate for isokinetic sampling percentages less than 90 percent, a second method, the area ratio method, was also used to calculate mass flow rates. An average of flow rates determined by the concentration method and the area ratio method were used in these cases.

A.6.3.3 Rotary Drum Dryer Outlet

The dryer outlet mass emissions results are presented in Tables A-29a and A-29b. Particle size results are presented in Figure A-12.

Nozzle plugging and isokinetic sampling problems which occurred at the predryer outlet were also encountered at the dryer outlet. In addition to this, negative ammonia emissions were determined during Test No. 1 at this outlet. This result is probably a reflection of the low excess ammonia present in the dryer and of the inaccuracies inherent in the ammonia analysis method.

A.6.3.4 Combined Predryer-Dryer Scrubber

Tables A-30a and A-30b present the results of the mass emission tests performed at this scrubber. The scrubber inlet results presented were determined by weighing the emissions from the predryer and dryer by flow rate. The results of the visible emission observations are presented in Table A-31. No problems were encountered during tests on the scrubber outlet.

A.6.3.5 Fluidized Bed Cooler Scrubber

Results of the mass emission tests performed at the cooler scrubber inlet and bypass are shown in Tables A-32a and A-32b.

Particle size results for the scrubber inlet and bypass are presented in Figures A-13 and A-14, respectively. Visible emissions observations, performed at the scrubber outlet and bypass, are presented in Tables A-33 and A-34, respectively.

No problems were encountered during testing at the fluidized bed cooler scrubber, although ammonia emissions during some of the tests were negative. This was probably due to inaccuracies inherent in the ammonia analyses and in the excess ammonia calculation.

A.6.3.5 Coater and Bagger

Visible emission observations were performed at the outlets from the coating and bagging fabric filters. These opacity readings are presented in Table A-35.

A.6.4 Process Operation During Testing

The process was operating at 56 to 80 percent of design capacity during testing. Production rates reflect market demands.

A review of the operating logs during testing revealed that there were no anomalies in process operation during the test period that affected emissions. Slight variations in operations which occurred were all within normal operative conditions.

A few minor problems occurred and are detailed below. At 9:00 a.m. on August 13, 1980, there was a ten minute decrease in production due to steam loss in the evaporator. On August 14, 1980 the system was down at 8:00 a.m., but returned to normal operation at 9:30 a.m. Also, on August 14, 1980 at 1:30 p.m. ammonium nitrate production was cut back five percent.

TABLE A-25a. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE PRILL TOWER INLET, OUTLET AND BYPASS (METRIC)[a]

Test No.	1	2	3	Ave.
General Data				
Date	8/12/80	8/12/80	8/13/80	
Isokinetic (%) In/Out/Bypass	99.5/105.7/98.4	100.7/103.7/98.1	100.5/99.2/103.3	100.4/102.9/99.9
Production Rate (Mg/hr)	21.1	22.2	23.1	22.1
Ambient Temp. (K)	305	308	302	305
Relative Humidtiy (%)	55	45	68	56
Exhaust Characteristics				
Flowrate (dnm^3/min)				
scrubber inlet:	1277	1269	1308	1285
scrubber outlet:	1447	1497	1468	1471
scrubber bypass:	6579	6958	5983	6507
Temperature (K)				
scrubber inlet:	325	326	322	325
scrubber outlet:	307	307	307	307
scrubber bypass:	315	319	313	316
Moisture (% Vol.)				
scrubber inlet:	2.82	2.94	3.28	3.01
scrubber outlet:	6.66	3.38	4.35	4.80
scrubber bypass:	1.99	2.35	3.02	2.44
Control Device Characteristics				
Device Type	Brinks Mist Eliminator			
Pressure Drop (kPa)	3.4	3.5	3.4	3.4
Liquor pH (Ave.)	4.06	5.36	3.87	4.43
Liquor AN Conc. (ppm) (Ave.)	73.4	76.6	71.8	73.9
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dnm^3)				
scrubber inlet:	0.0364	0.0524	0.0547	0.0478
scrubber outlet:	0.00371	0.00336	0.00796	0.00501
scrubber bypass:	0.0104	0.0130	0.0152	0.0129
Emission Rate (kg/hr)				
scrubber inlet:	2.79	3.99	4.29	3.69
scrubber outlet:	0.321	0.303	0.703	0.442
scrubber bypass:	4.11	5.41	5.47	5.00
total bypass and outlet:	4.43	5.71	6.17	5.44
Emission Factor (g/kg)				
scrubber inlet:	0.132	0.180	0.186	0.167
scrubber outlet:	0.015	0.014	0.031	0.020
scrubber bypass:	0.195	0.244	0.237	0.226
total bypass and outlet:	0.210	0.257	0.267	0.246
Collection Efficiency (%)				
scrubber:	88.5	92.4	83.6	88.0
total:	35.8	39.2	36.8	37.4
Ammonia Emissions				
Ammonia Conc. (gr/dnm^3)				
scrubber inlet:	0.0344	0.0302	0.0236	0.0293
scrubber outlet:	0.0120	0.0105	0.0116	0.0114
scrubber bypass:	0.0016	0.0015	0.0015	0.0015
Emission Rate (kg/hr)				
scrubber inlet:	2.632	2.302	1.851	2.259
scrubber outlet:	1.043	0.943	1.025	1.007
scrubber bypass:	0.631	0.631	0.526	0.599
total bypass and outlet:	1.674	1.574	1.551	1.606
Emission Factor (g/kg)				
scrubber inlet:	0.125	0.101	0.080	0.102
scrubber outlet:	0.050	0.043	0.045	0.046
scrubber bypass:	0.030	0.029	0.023	0.027
Total bypass and outlet:	0.080	0.071	0.067	0.073
Collection Efficiency (%)				
scrubber:	60.2	57.7	44.4	55.4
total:	51.5	55.0	65.4	56.2

[a] The inlet and bypass results were obtained by weighing the individual results at each of the three sampling points. Pounds per hour values were calculated by assuming that the grain loadings measured at one point existed at the other two points, and then multiplying by the total flowrate.

TABLE A-25b. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE PRILL TOWER SCBUBBER INLET, OUTLET AND BYPASS (ENGLISH)[a]

Test No.	1	2	3	Ave.
General Data				
Date	8/12/80	8/12/80	8/13/80	
Isokinetic (%) In/Out/Bypass	99.9/105.7/98.4	100.7/103.7/98.1	100.5/99.2/103.3	100.4/102.9/99.9
Production Rate tons/hr	23.3	24.5	25.5	24.4
Ambient Temp. °F	90	95	85	90
Relative Humidity (%)	55	45	68	56
Exhaust Characteristics				
Flowrate (dscfm)				
scrubber inlet:	45,130	44,850	46,220	45,400
scrubber outlet:	51,120	52,910	51,870	51,970
scrubber bypass:	232,460	245,870	211,417	229,920
Temperature (°F)				
scrubber inlet:	126	128	120	125
scrubber outlet:	94	93	94	94
scrubber bypass:	107	115	104	109
Moisture (% Vol.)				
scrubber inlet:	2.82	2.94	3.28	3.01
scrubber outlet:	6.66	3.38	4.35	4.80
scrubber bypass:	1.99	2.35	3.02	2.44
Control Device Characteristics				
Device Type	Brinks Mist Eliminator			
Pressure Drop (in. W.G.)	13.7	14.2	13.6	13.8
Liquor pH (Ave.)	4.06	5.36	3.87	4.43
Liquor AN Conc. (ppm) (Ave.)	73.4	76.6	71.8	73.9
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)				
scrubber inlet:	0.0159	0.0229	0.0239	0.0209
scrubber outlet:	0.00162	0.00147	0.00348	0.00219
scrubber bypass:	0.00455	0.00566	0.00665	0.00562
Emission Rate (lb/hr)				
scrubber inlet:	6.150	8.803	9.468	8.133
scrubber outlet:	0.708	0.667	1.549	0.975
scrubber bypass:	9.066	11.928	12.051	11.015
total bypass and outlet:	9.774	12.595	13.600	11.990
Emission Factor (lb/ton)				
scrubber inlet:	0.264	0.359	0.371	0.333
scrubber outlet:	0.030	0.027	0.061	0.040
scrubber bypass:	0.389	0.487	0.473	0.451
total bypass and outlet:	0.419	0.514	0.534	0.491
Collection Efficiency (%)				
scrubber:	88.5	92.4	83.6	88.0
total:	35.8	39.2	36.8	37.4
Ammonia Emissions				
Ammonia Conc. (gr/dscf)				
scrubber inlet:	0.0150	0.0132	0.0103	0.0128
scrubber outlet:	0.00526	0.00459	0.00508	0.00498
scrubber bypass:	0.00070	0.00066	0.00064	0.00067
Emission Rate (lb/hr)				
scrubber inlet:	5.802	5.074	4.081	4.981
scrubber outlet:	2.30	2.08	2.26	2.22
scrubber bypass:	1.39	1.39	1.16	1.32
total bypass and outlet:	3.69	3.47	3.42	3.54
Emission Factor (lb/ton)				
scrubber inlet:	0.249	0.201	0.160	0.204
scrubber outlet:	0.099	0.085	0.089	0.091
scrubber bypass:	0.060	0.057	0.045	0.054
total bypass and outlet:	0.159	0.142	0.134	0.145
Collection Efficiency (%)				
scrubber:	60.2	57.7	44.4	55.4
total:	51.5	55.0	65.4	56.2

[a] The inlet and bypass results were obtained by weighing the individual results at each of the three sampling points. Pounds per hour values were calculated by assuming that the grain loadings measured at one point existed at the other two points, and then multiplying by the total flowrate.

TABLE A-26. PLANT Z: OPACITY READINGS AT THE PRILL TOWER SCRUBBER OUTLET

Date	Run Number	Six-Minute Time Period	Average Opacity (Percent)	Date	Run Number	Six-Minute Time Period	Average Opacity (Percent)
8-12-80	1	1046 - 1051	0	8-13-80	3	0845 - 0850	0
		1052 - 1057	0			0851 - 0856	0
		1058 - 1103	0			0857 - 0902	0
		1104 - 1109	0			0903 - 0908	0
		1110 - 1115	0			0909 - 0914	0
		1116 - 1121	0			0915 - 0920	0
		1122 - 1127	0			0921 - 0926	0
		1128 - 1133	0			0927 - 0932	0
		1134 - 1139	0			0933 - 0938	0
		1140 - 1145	0			0939 - 0944	0
		1147 - 1152	0			0945 - 0950	0
		1153 - 1158	0			0951 - 0956	0
		1159 - 1204	0			0957 - 1002	0
		1205 - 1210	0			1003 - 1008	0
		1211 - 1216	0			1009 - 1014	0
		1217 - 1222	0			1015 - 1020	0
		1223 - 1228	0			1021 - 1026	0
		1229 - 1234	0			1027 - 1032	0
		1235 - 1240	0			1033 - 1038	0
		1241 - 1246	0			1039 - 1044	0
		Average	0			1045 - 1050	0
8-12-80	2	1520 - 1525	0			1051 - 1056	0
		1526 - 1531	0			1255 - 1300	0
		1532 - 1537	0			1301 - 1306	0
		1538 - 1543	0			1307 - 1312	0
		1544 - 1549	0			1313 - 1318	0
		1550 - 1555	0			1319 - 1324	0
		1556 - 1601	0			1325 - 1330	0
		1602 - 1607	0			1331 - 1336	0
		1608 - 1613	0			1337 - 1342	0
		1614 - 1619	0			1343 - 1348	0
		1620 - 1625	0			1349 - 1354	0
		1626 - 1631	0			1355 - 1400	0
		1632 - 1637	0			1401 - 1406	0
		1638 - 1643	0			1407 - 1412	0
		1644 - 1649	0			1413 - 1418	0
		1650 - 1655	0			1419 - 1424	0
		1656 - 1701	0			1425 - 1430	0
		1702 - 1707	0			1431 - 1436	0
		1708 - 1713	0			1437 - 1442	0
		1714 - 1719	0			1443 - 1448	0
		Average	0			1449 - 1454	0
						Average	0

TABLE A-27. PLANT Z: OPACITY READINGS AT THE PRILL TOWER SCRUBBER BYPASS

Location	Date	Run Number	Six-Minute Time Period	Average Opacity (Percent)	Location	Date	Run Number	Six-Minute Time Period	Average Opacity (Percent)
Bypass B	8-12-80	1	1049 - 1054	7.7	Bypass C	8-13-80	3	0952 - 0957	0
			1055 - 1100	7.5				0958 - 1003	0
			1101 - 1106	7.1				1004 - 1009	0
			1107 - 1112	5.6				1010 - 1015	0
			1113 - 1118	7.1				1016 - 1021	0
			1119 - 1124	4.8				1022 - 1027	0
			1125 - 1130	5.8				1028 - 1033	0
			1131 - 1136	6.9				1034 - 1039	0
			1137 - 1142	6.3				1040 - 1045	0
			1143 - 1148	8.3				1046 - 1051	0
			1149 - 1154	7.1				1052 - 1057	0
			1155 - 1201	6.3				1058 - 1103	0
			1202 - 1206	6.0				1104 - 1109	0
			1207 - 1212	6.5				1110 - 1115	0
			1213 - 1218	6.3				1116 - 1121	0
			1219 - 1224	5.2				1122 - 1119	0
			1225 - 1230	5.4				1120 - 1133	0
			1231 - 1236	6.7				1134 - 1139	0
			1237 - 1242	6.9				1140 - 1145	0
			1243 - 1248	5.6				1146 - 1151	0
			Average	6.4				Average	0
Bypass A		2	1520 - 1525	8.3					
			1526 - 1531	7.3					
			1532 - 1537	7.5					
			1538 - 1543	6.7					
			1544 - 1549	6.5					
			1550 - 1555	6.3					
			1556 - 1501	6.5					
			1602 - 1607	5.2					
			1608 - 1613	5.6					
			1614 - 1619	5.4					
			1620 - 1625	6.3					
			1626 - 1631	7.5					
			1632 - 1637	6.0					
			1638 - 1643	5.6					
			1644 - 1649	5					
			1650 - 1655	5					
			1656 - 1701	5					
			1702 - 1707	5					
			1708 - 1713	5					
			1714 - 1719	5					
			Average	6.0					

TABLE A-28a. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE PREDRYER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	8/14/80	8/14/80	8/14/80	
Isokinetic (%)	83.9	93.4	93.1	90.1
Production Rate (Mg/hr)	20.0	19.9	18.5	19.5
Ambient Temp. (K)	306	308	306	307
Relative Humidity (%)	56	46	54	52
Exhaust Characteristics				
Flowrate (dnm^3/min)	1088	1095	1096	1093
Temperature (K)	339	339	339	339
Moisture (% Vol.)	4.8	3.6	3.5	4.0
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	10.63	11.31	11.57	11.18
Emission Rate* (kg/hr)	637	744	761	714
Emission Factor (g/kg)	31.91	39.21	21.11	37.28
Ammonia Emissions				
Ammonia Conc. (g/dnm^3)	0.0321	0.1443	0.0616	0.0772
Emission Rate* (kg/hr)	2.53	9.48	4.15	5.40
Emission Factor (g/kg)	0.127	0.50	0.224	0.292

*For runs with percent isokinetic less than 90%, mass flowrates (kg/hr) presented here are averages of mass flowrates calculated by concentration method and area ratio method.

TABLE A-28b. SUMMARY OF EMISSION TEST RESULTS FOR THE PREDRYER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	8/14/80	8/14/80	8/14/80	
Isokinetic (%)	83.9	93.4	93.1	90.1
Production Rate tons/hr	22.0	20.9	20.4	21.1
Ambient Temp. °F	92	95	92	93
Relative Humidity (%)	56	46	54	52
Exhaust Characteristics				
Flowrate (dscfm)	38440	38680	38720	38610
Temperature (°F)	151	151	151	151
Moisture (% Vol.)	4.8	3.6	3.5	4.0
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	4.64	4.94	5.05	4.88
Emission Rate* (lb/hr)	1404	1639	1677	1573
Emission Factor (lb/ton)	63.82	78.42	42.21	74.55
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	0.0140	0.06303	0.0269	0.0337
Emission Rate* (lb/hr)	5.58	20.9	9.14	11.9
Emission Factor (lb/ton)	0.254	1.00	0.448	0.583

*For runs with percent isokinetic less than 90% mass flowrates (lb/hr) presented here are averages of mass flowrates calculated by concentration method and area ratio method.

TABLE A-29a. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE DRYER OUTLET (METRIC)

Test No.	1	2	3	Ave.
General Data				
Date	8/14/80	8/14/80	8/14/80	
Isokinetic (%)	83.3	84.9	83.0	83.7
Production Rate (Mg/hr)	20.0	19.9	18.5	19.5
Ambient Temp. (K)	306	308	306	307
Relative Humidity (%)	56	46	54	52
Exhaust Characteristics				
Flowrate (dnm^3/min)	955	988	962	967
Temperature (K)	336	334	335	335
Moisture (% Vol.)	5.2	4.5	4.4	4.7
Ammonium Nitrate Emissions				
Particulate Conc. (g/dnm^3)	29.54	36.87	34.58	33.66
Emission Rate[a] (kg/hr)	1552	2016	1814	1794
Emission Factor (g/kg)	77.75	106.32	97.99	93.70
Ammonia Emissions				
Ammonia Conc. (g/dnm)	Negative	0.2725	1.079	0.449[b]
Emission Rate[a] (kg/hr)		14.06	57.61	24.36
Emission Factor (g/kg)		0.742	3.113	1.300[b]

[a] For runs with isokinetic percent less than 90% mass flowrates (kg/hr) presented here are averages of mass flowrates calculated by concentration method and area ratio method.

[b] The average was calculated by assuming Run 1 values are zero.

TABLE A-29b. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE DRYER OUTLET (ENGLISH)

Test No.	1	2	3	Ave.
General Data				
Date	8/14/80	8/14/80	8/14/80	
Isokinetic (%)	83.3	84.9	83.0	83.7
Production Rate tons/hr	22.0	20.9	20.4	21.10
Ambient Temp. °F	92	95	92	93
Relative Humidity (%)	56	46	54	52
Exhaust Characteristics				
Flowrate (dscfm)	33,750	34,900	33,890	34,180
Temperature (°F)	146	142	144	144
Moisture (% Vol.)	5.2	4.5	4.4	4.7
Ammonium Nitrate Emissions				
Particulate Conc. (gr/dscf)	12.9	16.1	15.1	14.7
Emission Rate[a] (lb/hr)	3421	4444	3998	3954
Emission Factor (lb/ton)	155.5	212.63	195.98	187.39
Ammonia Emissions				
Ammonia Conc. (gr/dscf)	Negative	0.119	0.471	0.196[b]
Emission Rate[a] (lb/hr)		31.0	127.0	53.70[b]
Emission Factor (lb/ton)		1.483	6.225	2.600[b]

[a] For runs with isokinetic percent less than 90% mass flowrates (lb/ton) presented here are averages of mass flowrates calculated by concentration method and area ratio method.

[b] The average was calculated by assuming Run 1 values are zero.

TABLE A-30a. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE COMBINED PREDRYER AND DRYER SCRUBBER (METRIC)[a]

Test No.		1	2	3	Ave.
General Data					
Date		8/14/80	8/14/80	8/14/80	
Isokinetic (%)		83.6/102.3	89.2/101.3	88.1/100.8	87.0/101.5
Production Rate (Mg/hr)		20.0	19.9	18.5	19.5
Ambient Temp. (K)		306	308	306	307
Relative Humidity (%)		56	46	54	52
Exhaust Characteristics					
Flowrate	inlet:	2044	2084	2056	2061
(dnm^3/min)	outlet:	2089	2070	2071	2077
Temperature	inlet:	338	337	337	337
(K)	outlet:	315	315	316	315
Moisture (% Vol.)	inlet:	5.0	4.0	3.9	4.3
	outlet:	4.6	4.8	4.1	4.5
Control Device Characteristics					
Device Type		Peabody Tray Scrubber			
Liquor pH (Ave.)		6.29	6.47	6.33	6.36
Liquor AN Conc. (ppm) (Ave.)		570	645	677	631
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	19.4	23.3	22.3	21.7
(g/dnm^3)	outlet:	0.0991	0.0936	0.107	0.0999
Emission Rate	inlet:	2189	2759	2574	2507
(kg/hr)	outlet:	12.4	11.6	13.3	12.4
Emission Factor	inlet:	109.66	145.53	139.10	131.00
(g/kg)	outlet:	0.623	0.613	0.718	0.6145
Collection Efficiency (%)		99.4	99.6	99.5	99.5
Ammonia Emissions					
Ammonia Conc.	inlet:	0.0321[b]	0.2052	0.5439	0.2604
(g/dnm^3)	outlet:	0.0698	0.1074	0.0669	0.0813
Emission Rate	inlet:	2.531[b]	11.653	29.502	14.561
(kg/hr)	outlet:	8.755	13.381	8.301	10.161
Emission Factor	inlet:	0.127[b]	0.6145	1.594	0.7785
(g/kg)	outlet:	0.439	0.7055	0.4485	0.531
Collection Efficiency (%)		Negative	Negative	97.2	31.8

[a] The inlet values are weighted by the predryer and dryer flowrates.

[b] Includes only the inlet predryer concentration, the dryer ammonia emissions were negative.

TABLE A-30b. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE COMBINED PREDRYER AND DRYER SCRUBBER (ENGLISH)[a]

Test No.		1	2	3	Ave.
General Data					
Date		8/14/80	8/14/80	8/14/80	
Isokinetic (%) In/Out		83.6/102.3	89.2/101.3	88.1/100.8	87.0/101.5
Production Rate tons/hr		22.0	20.9	20.4	21.1
Ambient Temp. °F		92	95	92	93
Relative Humidity (%)		56	46	54	52
Exhaust Characteristics					
Flowrate	inlet:	72,190	73,580	72,610	72,790
(dscfm)	outlet:	73,770	73,100	73,120	73,330
Temperature	inlet:	149	147	148	148
(°F)	outlet:	108	108	110	109
Moisture (% Vol.)	inlet:	5.0	4.0	3.9	4.3
	outlet:	4.6	4.8	4.1	4.5
Control Device Characteristics					
Device Type		Peabody Tray Scrubber			
Liquor pH (Ave.)		6.29	6.47	6.33	6.36
Liquor AN Conc. (ppm)		570	645	677	631
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	8.50	10.2	9.74	9.48
(gr/dscf)	outlet:	0.0433	0.0409	0.0467	0.0436
Emission Rate	inlet:	4825	6083	5675	5528
(lb/hr)	outlet:	27.4	25.6	29.3	27.4
Emission Factor	inlet:	219.32	291.05	278.19	261.99
(lb/ton)	outlet:	1.245	1.225	1.436	1.299
Collection Efficiency (%)		99.4	99.6	99.5	99.5
Ammonia Emissions					
Ammonia Conc.	inlet:	0.0140[b]	0.0896	0.2375	0.1137
(gr/dscf)	outlet:	0.0305	0.0469	0.0292	0.0355
Emission Rate	inlet:	5.58[b]	25.69	65.04	32.10
(lb/hr)	outlet:	19.3	29.5	18.3	22.4
Emission Factor	inlet:	0.254[b]	1.229	3.188	1.557
(lb/ton)	outlet:	0.877	1.411	0.897	1.062
Collection Efficiency		Negative	Negative	97.2	31.8

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[a] The inlet values are weighted by the predryer and dryer flowrates.

[b] Includes only the inlet predryer concentration, the dryer ammonia emissions were negative.

TABLE A-31. PLANT Z: OPACITY READINGS AT THE COMBINED PREDRYER-DRYER SCRUBBER OUTLET

Date	Run Number	Six-Minute Time Period	Average Opacity (Percent)
8-14-80	1	1105 - 1110	0
		1111 - 1116	0
		1117 - 1122	0
		1123 - 1128	0
		1129 - 1134	0
		1135 - 1140	0
		1141 - 1146	0
		1147 - 1152	0
		1153 - 1158	0
		1159 - 1204	0
		1205 - 1210	0
		1211 - 1216	0
		1217 - 1222	0
		1223 - 1228	0
		1229 - 1234	0
		1235 - 1240	0
		1241 - 1246	0
		1247 - 1252	0
		1253 - 1258	0
		1259 - 1304	0
		Average	0
8-14-80	2	1510 - 1515	0
		1516 - 1521	0
		1522 - 1527	0
		1528 - 1533	0
		1534 - 1539	0
		1540 - 1545	0
		1546 - 1551	0
		1552 - 1557	0
		1558 - 1603	0
		1604 - 1609	0
		1610 - 1615	0
		1616 - 1621	0
		1622 - 1627	0
		1628 - 1633	0
		1634 - 1639	0
		1640 - 1645	0
		1646 - 1651	0
		1652 - 1657	0
		1658 - 1703	0
		1704 - 1709	0
		Average	0
8-14-80	3	1710 - 1715	0.6
		1716 - 1721	2.3
		1722 - 1727	3.1
		1728 - 1733	1.5
		1734 - 1739	0.8
		1740 - 1745	1.5
		1746 - 1751	0
		1752 - 1757	0.2
		1758 - 1803	0.6
		1804 - 1809	0.2
		1810 - 1815	0
		1816 - 1821	0
		1822 - 1827	0
		1828 - 1833	0
		1834 - 1839	0
		1840 - 1845	0
		1846 - 1851	0
		1852 - 1857	0
		1858 - 1903	0
		1904 - 1909	0
		Average	0.5

TABLE A-32a. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE COOLER SCRUBBER INLET AND BYPASS (METRIC)

Test No.		1	2	3	Ave.
General Data					
Date		8/15/80	8/15/80	8/16/80	
Isokinetic (%) In/Bypass		99.7/101.5	100.4/102.2	100.6/103.2	100.2/102.3
Production Rate (Mg/hr)		19.1	18.5	20.3	
Ambient Temp. (K)		304	305	301	304
Relative Humidity (%)		67	62	77	69
Exhaust Characteristics					
Flowrate	inlet:	1160	1145	1142	1149
(dnm^3/min)	bypass:	569	540	543	551
Temperature	inlet:	325	327	326	326
(K)	bypass:	318	319	319	319
Moisture (% Vol.)	inlet:	3.18	3.20	3.67	3.35
	bypass:	2.63	2.58	2.75	2.65
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	12.89	8.885	9.755	10.51
(g/dnm^3)	bypass:	0.175	0.232	0.186	0.1857
Emission Rate	inlet:	896	610	668	724
(kg/hr)	bypass:	5.99	7.48	6.08	6.12
Emission Factor	inlet:	47.02	32.94	32.86	37.54
(g/kg)	bypass:	0.315	0.405	0.299	0.318
	total:	47.33	33.35	33.16	37.85
Ammonia Emissions					
Ammonia Conc.	inlet:	0.2405	Negative	Negative	0.0802
(g/dnm^3)	bypass:	0.0027	0.0013	Negative	0.0014
Emission Rate	inlet:	16.78	Negative		5.58
(kg/hr)	bypass:	0.0939	0.0422		0.045
Emission Factor	inlet:	0.881	Negative		0.294
(g/kg)	bypass:	0.005	0.0025		0.0025
	total:	0.886	-		0.296

*Averages calculated by assuming that the negative numbers are zero.

TABLE A-32b. PLANT Z: SUMMARY OF EMISSION TEST RESULTS FOR THE COOLER SCRUBBER INLET AND BYPASS (ENGLISH)

Test No.		1	2	3	Ave.
General Data					
Date		8/15/80	8/15/80	8/16/80	
Isokinetic (5) In/Bypass		99.7/101.5	100.4/102.2	100.6/103.2	100.2/102.3
Production Rate tons/hr		21.0	20.4	22.4	21.3
Ambient Temp. °F		88	90	83	87
Relative Humidity (%)		67	62	77	69
Exhaust Characteristics					
Flowrate	inlet:	40,970	40,450	40,350	40,590
(dscfm)	bypass:	20,120	19,070	19,190	19,460
Temperature	inlet:	126	129	127	127
(°F)	bypass	113	114	115	114
Moisture (% Vol.	inlet	3.18	3.20	3.67	3.35
	bypass	2.63	2.58	2.75	2.65
Ammonium Nitrate Emissions					
Particulate Conc.	inlet:	5.63	3.88	4.26	4.59
(gr/dscf)	bypass:	0.0764	0.1011	0.0813	0.0811
Emission Rate	inlet:	1975	1344	1472	1596
(lb/hr)	bypass:	13.2	16.5	13.4	13.5
Emission Factor	inlet:	94.048	65.882	65.714	75.07
(lb/ton)	bypass:	0.629	0.809	0.598	0.635
	total:	94.667	66.691	66.312	75.705
Ammonia Emissions					
Ammonia Conc.	inlet:	0.105	Negative	Negative	0.035*
(gr/dscf)	bypass:	0.0012	0.00057	Negative	0.00059
Emission Rate	inlet:	37.0	Negative		12.3
(lb/hr)	bypass:	0.207	0.093		0.100
Emission Factor	inlet:	1.762	Negative		0.587
(lb/ton)	bypass:	0.010	0.005		0.005
	total:	1.772	-		0.592

*Averages calculated by assuming that the negative numbers are zero.

TABLE A-33. PLANT Z: OPACITY READINGS AT THE FLUIDIZED BED SCRUBBER OUTLET

Date	Run* Number	Six-Minute Time Period	Average Opacity (Percent)
8-14-80		1450 - 1455	5
		1456 - 1501	5
		1502 - 1507	5
		1508 - 1513	5
		1514 - 1519	5
		1520 - 1525	5
		1526 - 1531	5
		1532 - 1537	5
		1538 - 1543	5
		1544 - 1549	5
		1550 - 1555	5
		1556 - 1501	5
		1602 - 1607	5
		1608 - 1613	5
		1614 - 1619	5
		1620 - 1625	5
		1626 - 1631	5
		1632 - 1637	5
		1638 - 1643	5
		1644 - 1649	5
		Average	5
8-15-80		1100 - 1105	0
		1106 - 1111	0
		1112 - 1117	0
		1118 - 1123	0
		1124 - 1129	0
		1130 - 1135	0
		1136 - 1141	0
		1142 - 1147	0
		1148 - 1153	0
	1	1154 - 1159	0
8-15-80	1	1200 - 1205	0
		1206 - 1211	0
		1212 - 1217	0
		1218 - 1223	0
		1224 - 1229	0
		1230 - 1235	1.9
		1236 - 1241	5
		1242 - 1247	5
		1248 - 1253	5
		1254 - 1259	5
		Average**	2.2

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*Run number of concurrent inlet and bypass emission tests.

**Average for 1200 - 1259 observation period.

TABLE A-34. PLANT Z: OPACITY READING AT THE FLUIDIZED BED COOLER SCRUBBER BYPASS

Date	Run Number	Six-Minute Time Period	Average Opacity (Percent)
8-15-80		1100 - 1105	0
		1106 - 1111	0
		1112 - 1117	0
		1118 - 1123	0
		1124 - 1129	0
		1130 - 1135	0
		1136 - 1141	0
		1142 - 1147	0
		1148 - 1153	0
	1	1154 - 1159	0
		Average	0
8-15-80		1210 - 1215	0
		1216 - 1221	0
		1222 - 1227	0
		1228 - 1233	0
		1234 - 1239	0
		1240 - 1245	0
		1246 - 1251	0
		1252 - 1257	0
		1258 - 1303	0
		1304 - 1309	0
		Average	0
8-15-80	2	1545 - 1550	0
		1551 - 1556	0
		1557 - 1602	0
		1603 - 1608	0
		1609 - 1614	0
		1615 - 1620	0
		1621 - 1626	0
		1627 - 1632	0
		1633 - 1638	0
		1639 - 1644	0
		Average	0

TABLE A-35. PLANT Z: OPACITY READINGS AT THE COATER AND SCRUBBER FABRIC FILTER OUTLETS

Coater Baghouse		
Date	Six-Minute Time Period	Average Opacity (Percent)
8-13-80	0845 - 0850	0
	0851 - 0856	0
	0857 - 0902	0
	0903 - 0908	0
	0909 - 0914	0
	0915 - 0920	0
	0921 - 0926	0
	0927 - 0932	0
	0933 - 0938	0
	0939 - 0944	0
	Average	0
8-13-80	1255 - 1300	0
	1301 - 1306	0
	1307 - 1312	0
	1313 - 1318	0
	1319 - 1324	0
	1325 - 1330	0
	1331 - 1336	0
	1337 - 1342	0
	1343 - 1348	0
	1349 - 1354	0
	1355 - 1359	0
	Average	0
8-13-80	1355 - 1400	0
	1401 - 1406	0
	1407 - 1412	0
	1413 - 1418	0
	1419 - 1424	0
	1425 - 1430	0
	1431 - 1436	0
	1437 - 1442	0
	1443 - 1448	0
	1449 - 1454	0
	Average	0

Bagging Baghouse		
Date	Six-Minute Time Period	Average Opacity (Percent)
8-14-80	1014 - 1019	0
	1020 - 1025	0
	1026 - 1031	0
	1032 - 1037	0
	1038 - 1043	0
	1044 - 1049	0
	1050 - 1055	0
	1056 - 1101	0
	1102 - 1107	0
	Average	0
8-14-80	1123 - 1128	0
	1129 - 1134	0
	1135 - 1140	0
	1141 - 1146	0
	1147 - 1152	0
	Average	0
8-14-80	1235 - 1240	0
	1241 - 1246	0
	1247 - 1252	0
	1253 - 1258	0
	1259 - 1304	0
	1305 - 1310	0
	1311 - 1316	0
	1317 - 1322	0
	1323 - 1328	0
	1329 - 1334	0
	1335 - 1340	0
	1341 - 1346	0
	1347 - 1352	0
	1353 - 1358	0
	Average	0

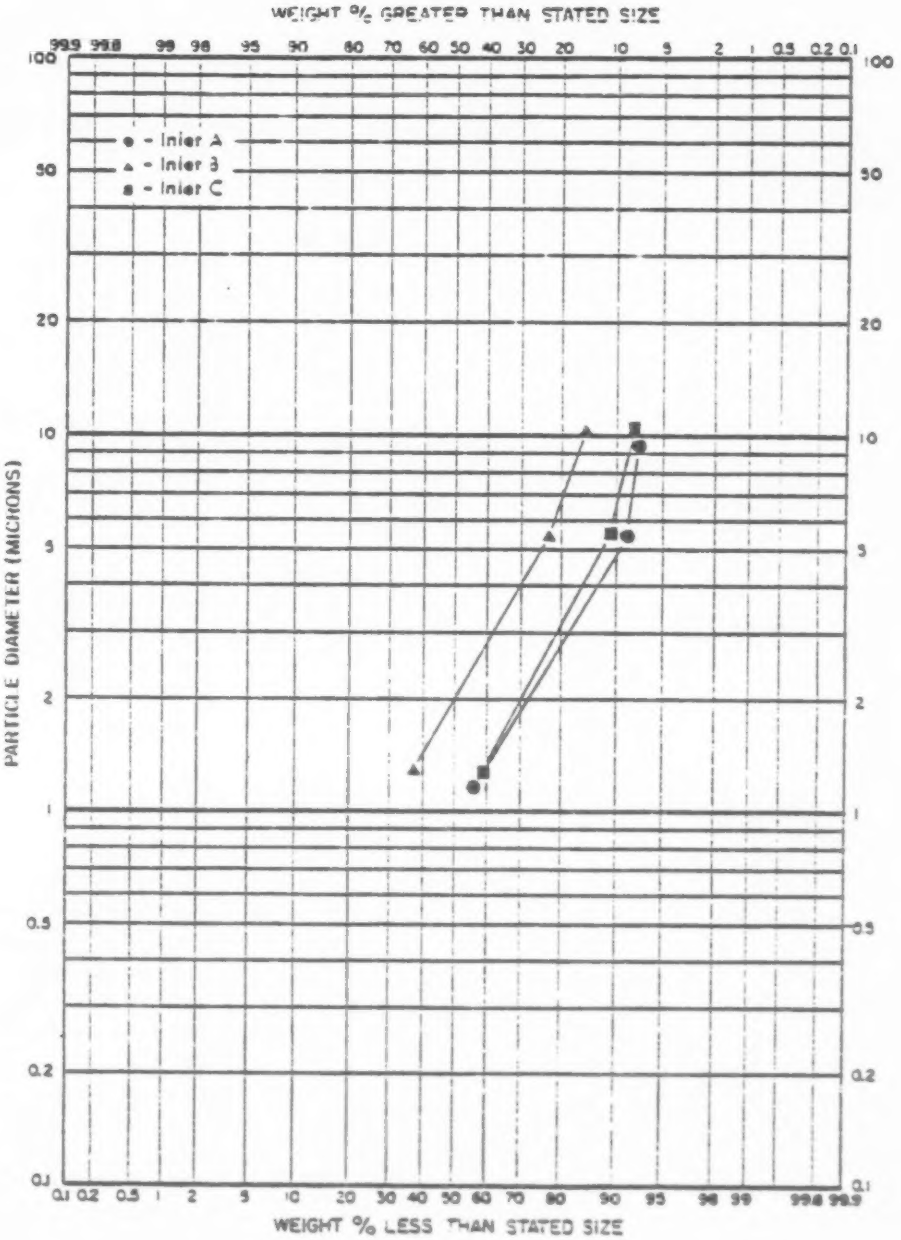

Figure A-9. Plant Z: Particle size results at the prill tower scrubber inlet.

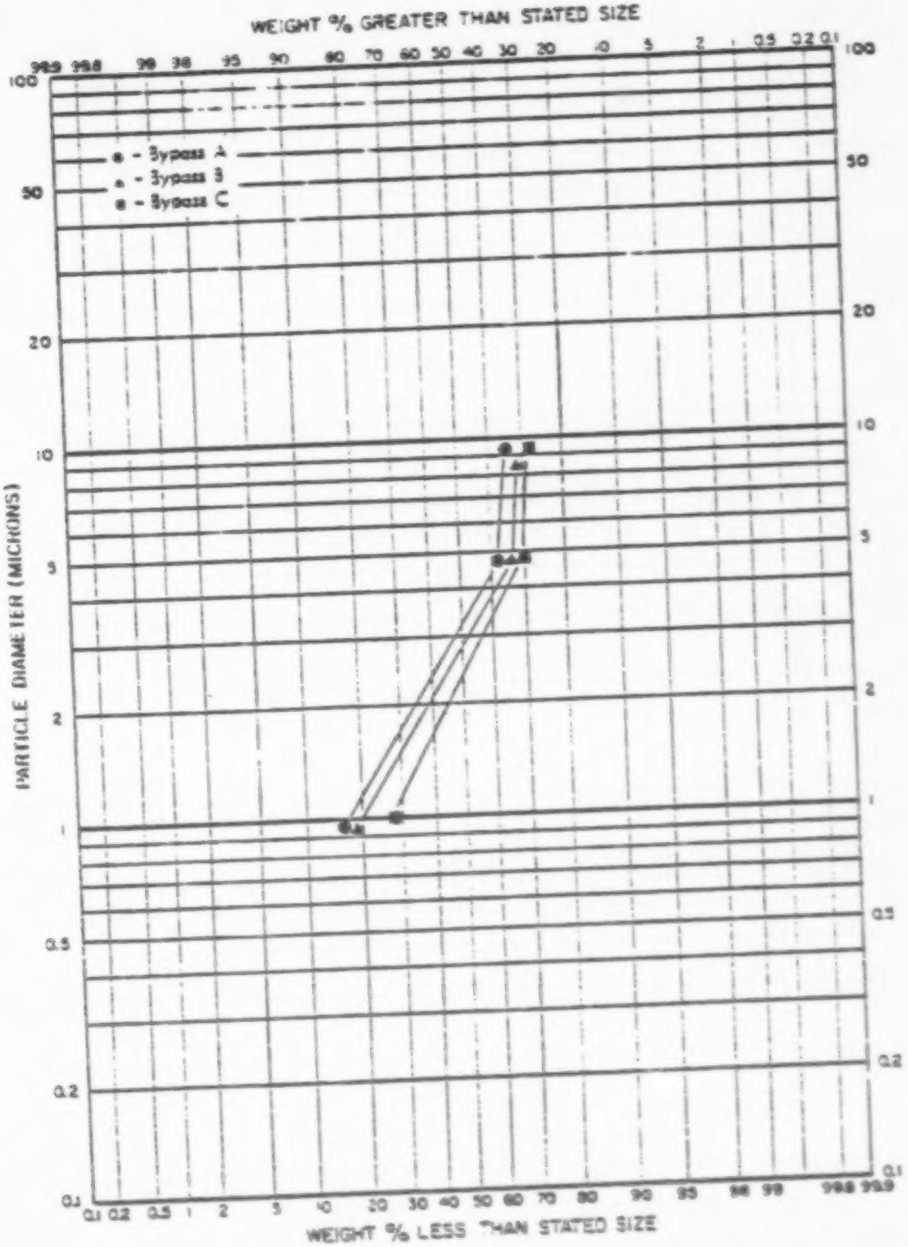

Figure A-10. Plant Z: Particle size results at the prill tower bypass.

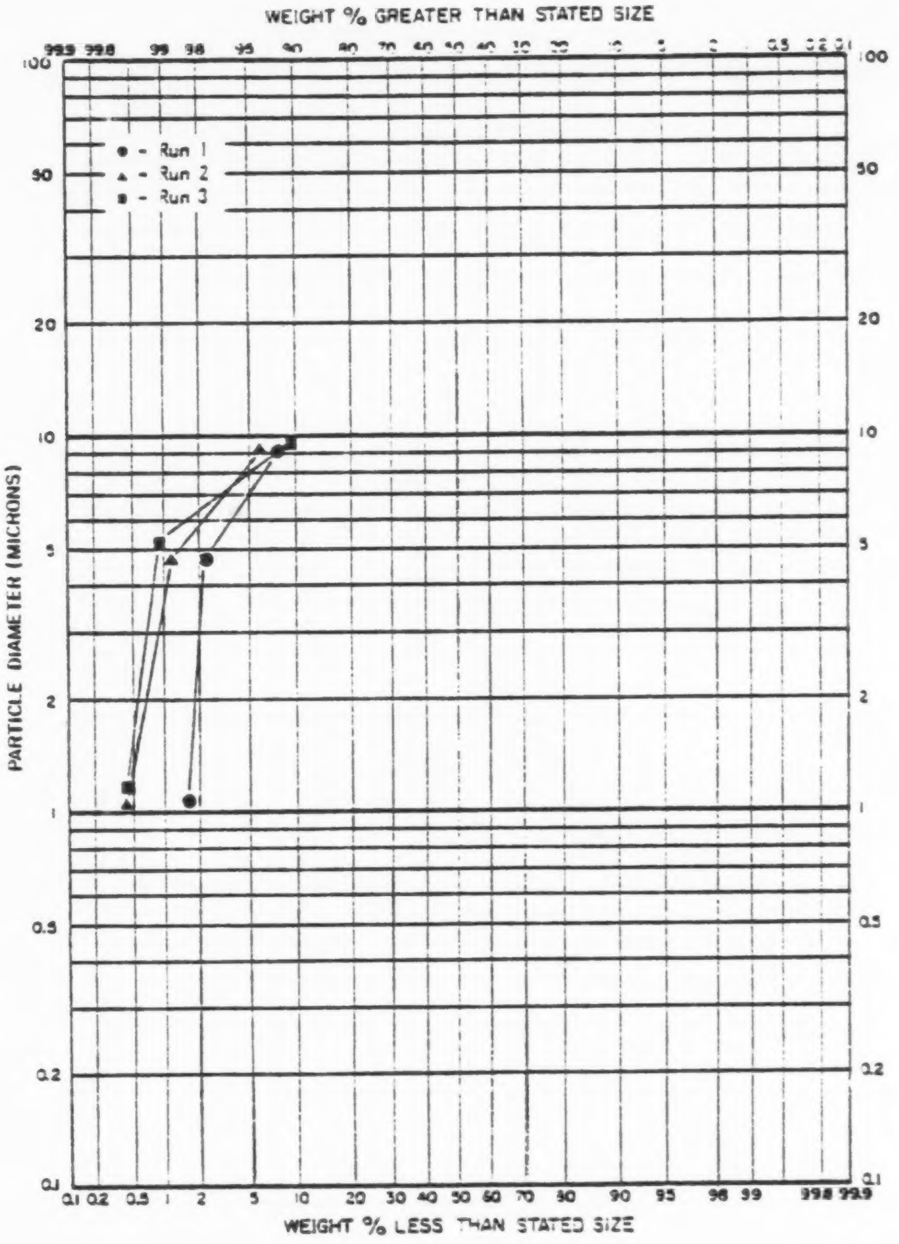

Figure A-11. Plant Z: Particle size results at the predryer outlet.

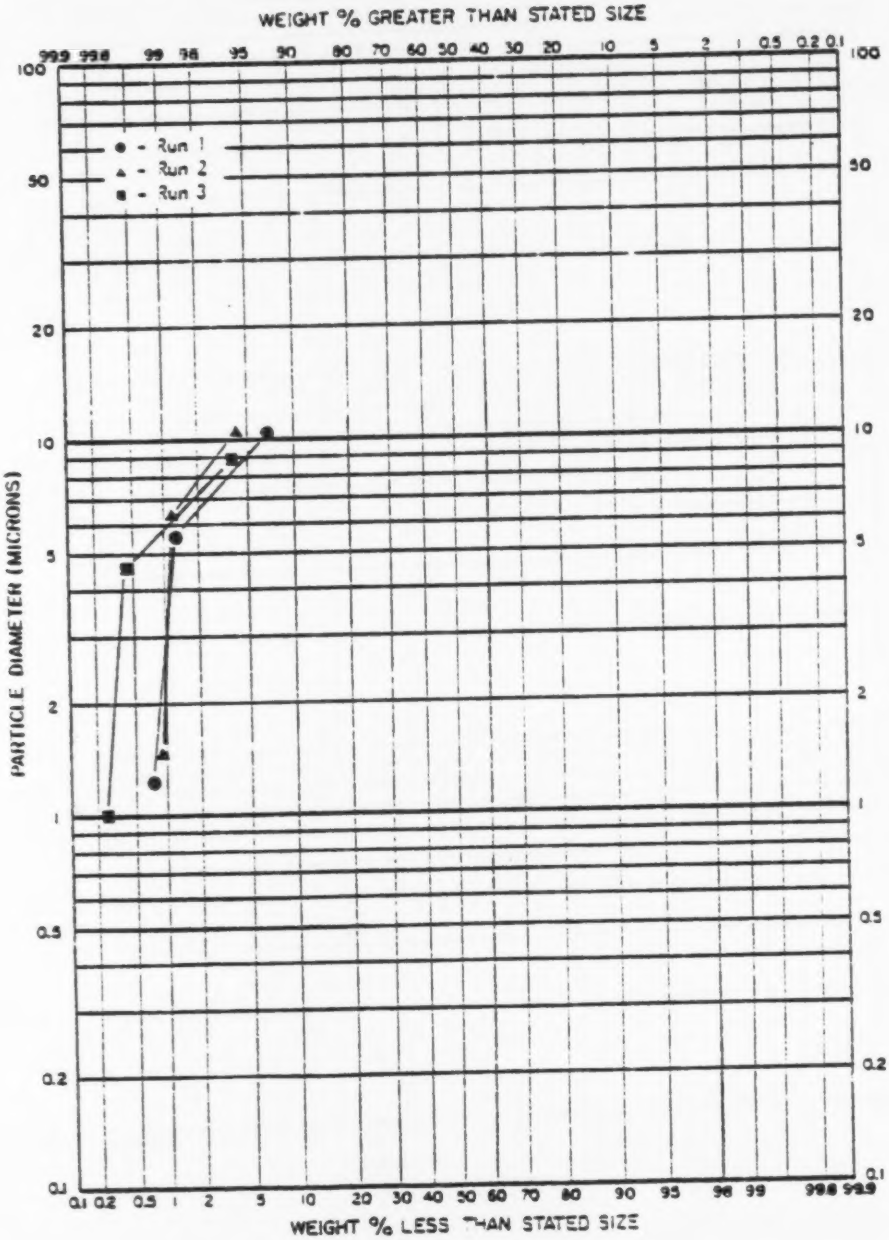

Figure A-12. Plant Z: Particle size results at the dryer outlet.

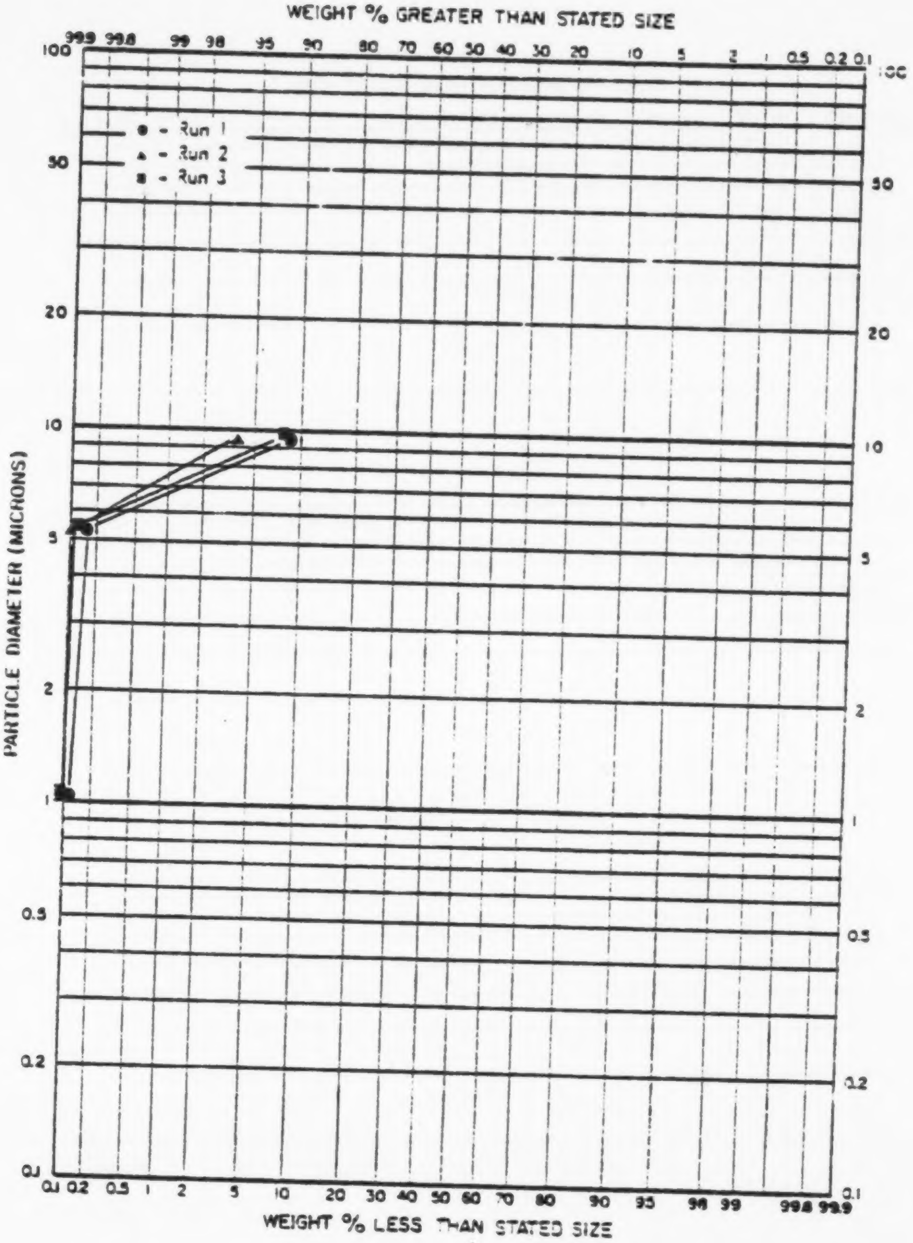

Figure A-13. Plant Z: Particle size results at the fluidized bed cooler outlet.

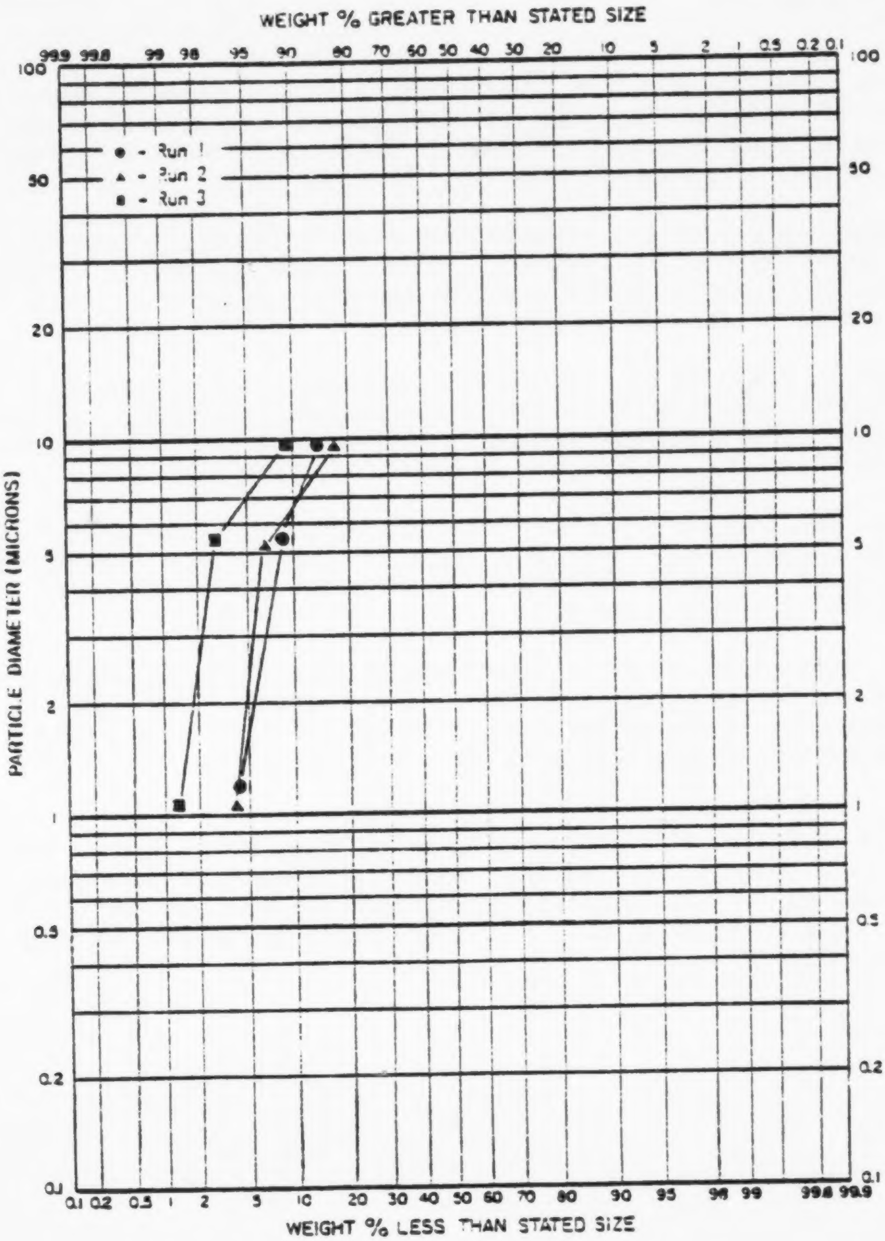

Figure A-14. Plant Z: Particle size results at the fluidized bed cooler bypass.

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APPENDIX B

Ammonium Nitrate Emission Measurement

B.1 Emission Measurement Methods

B.1.1 Background

The standard method for determining particulate emissions for stationary sources is EPA Method 5, whereby a particulate sample is extracted isokinetically from a source and is collected on a heated filter. The particulate mass is then determined gravimetrically. Initial evaluations by EPA and others of the applicability of Method 5 for ammonium nitrate (AN) sampling indicated that in fact the standard procedures of Method 5 would not be practical.[1,2] Factors that affected the sampling and analysis procedures of Method 5 included the following:

- High water-solubility of AN (greater than 1 gram per ml water);
- Relatively high vapor pressure and volatility of AN (AN decomposes at 483 K (410°F)); and,
- High moisture levels present at certain AN emission sources (percent moisture exceeding 50 percent).

As a result of these factors, major modifications to Method 5 were adopted. A summary of these modifications and the reasons for each are presented in the remainder of Section B.1.

B.1.2 Brief Summary of AN Method Development

Preliminary emission testing programs by industry and EPA in 1975 and 1976 demonstrated the applicability of the following modifications to Method 5 for AN sampling and analysis:

- Use of water-filled impingers as the primary AN collection devices;
- Placement of the filter after the water impingers as a back-up collector;
- Use of a specific ion electrode (SIE) for measurement of AN in the impinger water;
- Use of a water rinse instead of an acetone rinse because of the explosion hazard when organic solvents mix with AN;

- Use of an in-stack orifice in high water-content sources where isokinetic sampling rates could not be maintained using Method 5 procedures.

Further minor modifications were incorporated into the AN method during six emission testing programs conducted by EPA from November 1978 to August 1980. The results of these programs demonstrated the applicability of the recommended EPA Method ("modified" Method 5; AN-MOD 5) for AN sampling and analysis. The modifications incorporated into AN-MOD 5 are summarized as follows:

- Use of five impingers in the following sequence: impingers 1 and 2 each contain 100 ml water (for AN collection), impinger 3 contains 100 ml 1N sulfuric acid (to protect sampling train components from ammonia), impinger 4 is empty and impinger 5 contains silica gel;
- Elimination of the in-train filter;
- Sample Recovery and Analysis: combine the contents of impingers 1 and 2 and the probe wash, filter for insoluble particulate, and analyze the filtrate for AN by SIE; measure the contents of impingers 3 and 4 for condensed moisture, and then discard the contents.

B.1.3 Detailed Development of AN Sampling and Analysis Method

B.1.3.1 Initial Method Development

Ammonium nitrate sampling modifications to Method 5 were needed because of the following source conditions:

- AN has a substantial vapor pressure even as a solid, and if a sample is heated in a probe or on a filter for extended periods of time it would tend to decompose.[3]
- Industry sources estimated that a large fraction of AN particulate matter would be small enough (less than 0.3 microns in diameter) to pass through a Method 5 filter.
- The high-water-solubility of AN and the potential ineffectiveness of a filter implied that water impingers in the sampling train would be an efficient AN particulate collector.

- Ammonia is an additional pollutant emitted from the AN manufacturing processes. Ammonia was considered a secondary pollutant in the test work plan but could not be efficiently collected in the Method 5 sampling train water impingers. Additional impingers containing acid would be required.
- Method 5 could not be performed effectively in high moisture sampling situations, such as at neutralizers and evaporators, because isokinetic sampling conditions could not be maintained.

Factors that would affect AN analysis procedures were the following:

- With water impingers as the primary particulate collector, the water contents of the sampling train impingers would have to be analyzed for AN.
- The volatility of AN would preclude rapid heating of the samples to evaporate water in order to do a gravimetric analysis. At the same time, evaporating large quantities of water without heating would be inefficient and tedious.
- The insoluble fraction of particulate emitted from AN sources was considered to be insignificant.
- The specific ion electrode procedure for AN analysis is applicable to a wide range of AN concentrations, can be performed easily and quickly in the field, and is recommended and widely used by industry. This procedure measures nitrate (NO_3^-) from which AN is calculated stoichiometrically.

An emission testing program was performed by plant personnel on neutralizer and evaporator emissions at an AN plant in July 1975.[2] Water impingers were used to collect AN particulate, an in-train glass-wool plug was placed after the water impingers, and nitrate analyses of the impinger contents were performed with a specific ion electrode. The Method 5 procedures for sample flowrate measurement and control were followed; however, the high moisture content of the sampled streams made isokinetic sampling difficult to maintain.

EPA conducted an emission testing program in March 1976 on a neutralizer stack at an AN facility.[2] The purpose of this initial program was to determine the applicability of the sampling and analysis procedures used during the 1975 program. In addition, evaluations of other Method 5 modifications were performed in order to develop an initial AN test method for the testing program. An in-stack orifice was used to control the sampling rate, and a heated filter was placed after the impingers. Field and laboratory samples were analyzed both gravimetrically and by the specific ion electrode (SIE) procedure. The results of this program showed that:

- The AN sampling and analysis method was practical and gave reproducible results;
- An in-stack orifice could be used successfully in high moisture content gas streams in order to maintain isokinetic sampling conditions; and,
- The SIE analysis procedure yielded results that agreed within 1 percent of known standards. Gravimetric results agreed only within 5 percent of known standards.

The AN sampling and analysis method recommended for the testing program in November 1978 included the following specific Method 5 modifications:

Sampling

- Six impingers in series, with the following sequence: impingers 1 and 2 each contain 100 ml water, impingers 3 and 4 each contain 100 ml 1N sulfuric acid, impinger 5 is empty, and impinger 6 contains silica gel.
- A filter, heated if necessary to prevent condensation, placed between impingers 2 and 3. Filter temperature should not exceed the decomposition temperature of AN 283 K (410°F).

Analysis

- Combine the contents of impingers 1 and 2, the probe washes and the train filter (allowing the filter catch to dissolve); filter this solution with a vacuum filtration apparatus to remove insoluble particulate; split the filtrate; analyze one portion for nitrate by SIE and the other portion for ammonia by direct nesslerization.[4]

- Combine the contents of impingers 3, 4, and 5 and analyze a portion for nitrate by SIE and a portion for ammonia by direct nesslerization.

The test work plan for the technical document included emission tests on all AN process units having significant emissions: neutralizers, evaporators, prill towers, granulators, predryers, dryers and coolers. The sampling method would differ slightly for the neutralizers and evaporators because of the high moisture content of these units. An in-stack orifice would be necessary in the sampling train at a neutralizer or evaporator in order to maintain isokinetic sampling conditions.

Insoluble particulate analysis was included in this initial method because most AN plants use a clay coating or additive to protect the final solid AN product. Some final product is often recycled back to the process liquors, and particulate emissions may result from the weak liquor used in scrubber systems. Additional sources of insoluble particulate are believed to be pipe scale and rust in the scrubber systems.

Ammonia was considered a secondary pollutant in the test work plan and is most efficiently collected in acid impingers. Two acid impingers were therefore included in the sampling train for ammonia collection. The in-train filter served as a backup collector to prevent the carry over of particulate or particulate-laden water droplets.

The AN collection medium (water) and the ammonia collection medium (acid) are separate during sampling and analysis because of the susceptibility of the nitrate SIE analysis procedure to interference in high ionic strength solutions.[13,14] Because of its high water solubility, nearly all sampled AN will be collected in the water impingers and very little collected in the acid impingers.

Ammonium nitrate in solution exists as nitrate ions and ammonium ions. Therefore, if only AN is emitted and sampled, then either nitrate or ammonia could be measured to quantify AN particulate emissions. In the AN production process, however, either ammonia or nitrate will be present in excess (AN is formed by combining ammonia and nitric acid). The emission tests for this study were all performed at AN facilities that operated with an excess of ammonia. Nitrate was therefore the limiting species and any measured nitrate originated as AN. Nitrate and ammonia analyses were performed during the tests in order to quantify AN particulate emissions. The excess species (ammonia) was sampled and analyzed to document its excess.

B.1.3.2 Emission Testing Program at the First Five Plants

From November 1978 through June 1979, EPA conducted five emission testing programs at five different AN plants using the above (modified Method 5) sampling and analytical procedures. Evaporator, granulator and cooler emissions were tested at the first AN plant, with an in-stack orifice used at the high moisture locations.[5] The in-train filter was analyzed separately for AN particulate and insoluble particulate. Less than 0.2% of the total AN catch was found on the filter. The percent insoluble particulate catch (insoluble particulate/total particulate) averaged about 3% for uncontrolled emissions and about 8% for controlled emissions. No AN was detected in the acid impingers.

At the second plant,[6] also tested in November 1978, controlled and uncontrolled cooler emissions were evaluated. The train filter was analyzed separately for particulate, and no AN was found on the filter. No AN was detected in the acid impingers. The percent insoluble particulate catch averaged about 0.2% for uncontrolled emissions and about 6% for controlled emissions.

The third plant[7] was tested in March 1979 for uncontrolled and controlled granulator emissions and uncontrolled cooler emissions. The train filter was combined with the water impinger contents and probe washes and was not analyzed separately. The percent insoluble particulate catch averaged about 0.02% for the granulator uncontrolled emissions, and about 4% for the granulator controlled emissions. Only very slight amounts of AN were detected in the uncontrolled granulator acid impingers (less than 0.5% of total catch). Significant amounts of AN were measured in the controlled granulator acid impingers (about 30% of total catch), but the interfering effects of the acid make these results suspect.[13,14]

The fourth plant[8] was tested in March 1979, for uncontrolled emissions from the predryer, dryer and cooler operations. The train filter was not analyzed separately. The percent insoluble particulate catch averaged about 0.6% of the total particulate catch for all the process operations tested. Approximately 3% of the total AN catch was detected in the acid impingers, and these results are suspect because of acid interference.[13,14]

The fifth plant[9] was tested in May and June 1979 for controlled and uncontrolled emissions from a prill tower, prill cooler, evaporators and neutralizers. The train filter was not analyzed separately. The percent insoluble particulate catch for uncontrolled emissions averaged 4.4%, 0.9%, and 1.2% at the prill tower, cooler and neutralizer, respectively; and 5.8%, 10%, and 18% for the controlled emissions at the same process units. Acid impinger samples were not analyzed for nitrate. The neutralizer and evaporator samples contained very high concentrations of ammonia compared to AN. As a result, some positive interference in the AN analyses of these samples was evident due to their high background ionic strength.

The results of these five emission testing programs demonstrated that:

- Little or no particulate is collected by the in-train filter;
- Nearly all AN is collected in the water impingers; and,
- The SIE nitrate analysis is subject to interference in high ionic strength solutions. This interference will normally be confined to neutralizer/evaporator emission samples.

B.1.3.4 Method Modifications

EPA further modified the AN sampling and analytical method to reflect the findings of the first five testing programs and to discontinue the requirement for ammonia sampling and analysis. No immediate need for an ammonia emissions evaluation was foreseen. The modifications consisted of the following:

Sampling

- Use of five impingers with the following sequence: impingers 1 and 2 each contain 100 ml water (for AN collection), impinger

3 contains 100 ml 1N H_2SO_4 (to protect sampling train components from ammonia), impinger 4 is empty and impinger 5 contains silica gel.

- Elimination of the in-train filter.

Analysis

- Combine the contents of impingers 1 and 2 and the probe washes; filter this combined solution for insoluble particulate and analyze the filtrate for nitrate by SIE.
- Measure the volume of the contents of impingers 3 and 4 for condensed moisture, and then discard the contents.

These modifications represent the recommended EPA Method (AN-MOD 5) for AN emission testing. In situations where ammonia sampling and analysis is of interest, an additional impinger (containing 100 ml 1N H_2SO_4) can be added to the train directly in front of the empty impinger. The contents of the first two impingers are then analyzed for nitrate by SIE and for ammonia by SIE or direct nesslerization. The contents of the third and fourth impingers are analyzed for ammonia only. The two ammonia analysis methods (SIE and direct nesslerization) have been shown to yield equivalent results.[10,11]

B.1.3.5 Sixth Emission Testing Program

EPA conducted a sixth emission testing program in August 1980 on controlled and uncontrolled prill tower, predryer, dryer and cooler emissions.[12] The recommended AN-MOD 5 was used and modified for ammonia sampling and analysis as described above. Ammonia analyses were performed with the SIE procedure. The percent insoluble particulate catch for the prill tower and dryer controlled emissions averaged 27% and 1.1%, respectively. The prill tower insoluble particulate was believed to be primarily clay coating material.

The results of this emission testing program demonstrated the utility and economy of the recommended method. The AN and ammonia SIE analytical methods required a minimum of equipment and field laboratory space and all analyses were performed on-site within 24 hours of sample collection. The ability to perform sample analyses quickly in the field allows for rapid determination of emission values and evaluation of sampling technique.

B.1.4 Potential Problems with the Recommended Method

Potential difficulties that could affect the use of the recommended method are:

- Decomposition of AN in the probe at temperatures exceeding 483 K (410°F);
- Interference in the nitrate SIE analysis procedure due to high ionic strength sample solutions;
- Emission tests performed at AN plants operating with excess nitric acid;
- Incomparability of AN-MOD 5 and Method 5 data.

By maintaining probe temperatures at about 6 K (10°F) above stack temperature, sample decomposition and moisture condensation in the probe can be avoided. Most emission control devices operate at or near saturation and at temperatures less than 322 K (120°F).

Interference in the nitrate analysis would be primarily confined to neutralizer or evaporator emission samples containing high concentrations of ammonia. The interference is characteristic of the operation of the nitrate SIE. Sample dilution may not eliminate the problem because the degree of interference depends on the relative strength of the interfering ion concentration. The analytical technique of known addition measurement can be used to estimate nitrate concentrations in high ionic strength solutions.[13]

A sampling and analytical method that would determine total ammonia would be required in order to measure AN emissions at plants operating with excess nitric acid (with ammonia therefore as the limiting species). With AN-MOD 5 there would be no way to distinguish between nitrate from AN emissions and nitrate from excess nitric acid.

B.1.5 Relationship of Data Gathered Under Test Programs to Data Gathered with the Recommended Method

The recommended AN-MOD 5 is identical to the method used on the emission testing programs with the exception of the following minor changes incorporated after the first five test programs:

- elimination of the in-train filter;
- elimination of acid impinger nitrate analyses; and,
- elimination of ammonia sampling and analysis.

These changes simplified the sampling and analytical method, eliminating unnecessary procedural steps. For this reason the data gathered during the test programs are comparable to data gathered with the recommended AN-MOD 5.

B.2 Performance Test Methods

AN-MOD 5 - "Determination of Particulate Emissions from Ammonium Nitrate Plants" - is the recommended test method for ammonium nitrate facilities. This method incorporates modifications to the standard Method 5 that reflect the unique characteristics of AN and AN sources, as discussed in Section B.1 above. These modifications are summarized as follows:

- Collection of ammonium nitrate in water impingers;
- Elimination of an in-train filter; and,
- Analysis of water impinger contents for nitrate by a specific ion electrode and for insoluble particulate by filtration and weighing.

Six emission testing programs conducted by EPA at AN facilities demonstrated that the recommended test method is a workable and efficient means for accurately sampling and analyzing ammonium nitrate emissions. During the course of these emission testing programs, the method was modified to its present form. The modifications eliminated procedures that were shown through the emission testing programs to be unnecessary. Therefore, as discussed in Section B.1, the data gathered during these testing programs will be comparable to data gathered using the recommended test method.

Four potential difficulties could affect the use of the recommended method:

- Decomposition of AN in the probe at elevated temperatures;
- Interference in the nitrate SIE analysis procedure due to high ionic strength sample solutions;

- Emission tests performed at AN plants operating with excess nitric acid; and,
- Incomparability of AN-MOD 5 and Method 5 data.

These difficulties are discussed in Section B.1. The interference problem is primarily confined to emission samples from neutralizers and evaporators.

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